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# MICHIGAN ACADEMY OF SCIENCE, ARTS AND LETTERS

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VOLUME VI

CONTAINING PAPERS SUBMITTED AT THE ANNUAL MEETING IN 1926

*(This volume contains papers in Botany only. Volume VII will contain papers in Anthropology, Economics, Geology, History, Language and Literature, and Zoölogy.)*

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# PAPERS

OF THE

# MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS

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UNIVERSITY OF MICHIGAN

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UNIVERSITY OF MICHIGAN

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# SUMATRAN PLANTS COLLECTED IN ASAHAN AND KAROLAND, WITH NOTES ON THEIR VERNACULAR NAMES*

HARLEY HARRIS BARTLETT

## INTRODUCTION

IN 1918 a collection of plants was made by native collectors under the direction of C. D. La Rue and the writer in Asahan on the East Coast of Sumatra and on the Karo plateau. Since most of the species, which were determined by Dr. E. D. Merrill at the Philippine Bureau of Science, proved to be common lowland types of broad distribution, the collection was of minor significance from a purely floristic standpoint. As a matter of fact, common species predominated because the collectors had been instructed to collect plants of which they or their companions knew the names and the uses. It is chiefly from an ethnobotanical standpoint, therefore, that the collection is interesting, since the specimens are vouchers for the application of the vernacular names. The latter are believed to have been recorded with unusual accuracy, since the specimens were the subject of no little *kampong* conversation and discussion during the process of collecting and drying.

So far as the collections proved to be of strictly botanical interest they were reported upon by Merrill,[1] who described four new species and noted the significant extensions of range. At the writer's request Dr. Merrill distributed the sets to the following herbaria: Philippine Bureau of Science; Rijksherba-

* Paper from the Department of Botany of the University of Michigan, No. 241.

[1] Merrill, E. D., "Notes on the Flora of Sumatra," *Phil. Journ. Sci.*, 14: 239–250. 1919.

rium, Leyden; Royal Botanic Gardens, Kew; National Herbarium, Washington; Gray Herbarium of Harvard University. As the collection was sent to Manila there were two series of numbers, those of Galoengi Marga Karokaro Sinoelingga, who collected in Asahan (nos. 1 to 70), and the Karo lands (nos. 71 to 338), and those of Ramit *alias* Limah Bidin Sirait Holboeng, collected in Asahan (nos. 1 to 165). These two series were thrown together at the Bureau of Science, where Galoengi's collections were numbered from 1 to 330, without maintaining correspondence between his original numbers and the new numbers. Bidin's collection continued the numbering from 331 to 495. A few plants collected by the writer near Balige, Toba, were included in the Bureau of Science series as nos. 496 to 502. Because of the lack of correspondence between the original numbers on the written labels which accompanied each sheet and the labels added in Manila, both numbers for each collection have been cited in the following notes in order to eliminate any possible confusion that might arise. The native collector's number is given first, followed by the Bartlett and La Rue number, abbreviated B. & La R.

Since there were numerous mistakes in transferring the data, botanists who may cite the specimens are warned to follow the data of the original hand-written labels in case they do not agree with the printed labels added at the Bureau of Science. The set sent to the National Herbarium lacks the original labels, and the Karoland plants are labelled incorrectly as from Asahan. In Dr. Merrill's article two type localities in Karoland are attributed to Asahan, as noted under *Oreocnide nivea* and *Memecylon La Ruei*. In the absence of the original labels, botanists should not cite the specimens without consulting the present enumeration.

Galoengi recorded vernacular names in his own language, Karo, even those of plants collected in Asahan. Bidin collected only in one limited district, Silo Maradja (= Silau Maradja), where he had been brought up and was thoroughly acquainted. He recorded names in the dialect spoken there, which will be called the Asahan dialect of Toba. This dialect is distinct

enough from Toba so that it can by no means be inferred that the names are always the same as in Toba. This word of caution is offered for the benefit of those who may utilize the names in linguistic comparisons or in the compilation of such a work as the admirable *Plantkundig Woordenboek* of De Clercq and Greshoff.[2] It will be observed by those acquainted with Toba that the Asahan dialect frequently has *a* instead of *o*, and *k* instead of *h*. In Asahan there is no avoidance of the sound written *tj* (= *ch* of English, not *tj* of Dutch), especially as a mutation of *s* following the final *s* of a closed syllable. This sound is not heard in Toba. Toba *ng-k* is pronounced and written *k-k* in Asahan, and *m-p* becomes *p-p*. Furthermore, in addition to the differences ascribed to mere phonetic modification of the Toba, the Asahan dialect has borrowed many words from Malay and from Simeloengoen.

In the *Plantkundig Woordenboek* the whole group of Batak languages or dialects are cited jointly as "Batak." I have attempted a more precise attribution of names, in the linguistic notes of the following lists, by searching for the "Batak" names of De Clercq and Greshoff in the dictionaries of Van der Tuuk,[3] Warneck[4] and Joustra.[5] These authorities have been so frequently consulted that they are not referred to in each particular instance in which they have been drawn upon. The most useful Malay dictionaries to the student of plant names will be found to be those of Wilkinson[6] and Winstedt.[7] The former incorporates the names published by Ridley.[8] The latter, although based upon Wilkinson's work, includes additional plant names identified by members of Straits Settlements Civil Service.

[2] De Clercq, F. S. A., and Greshoff, M., *Nieuw Plantkundig Woordenboek voor Nederlandsch Indië*. Amsterdam, 1909.

[3] Van der Tuuk, H. N., *Bataksch-Nederduitsch Woordenboek*. Amsterdam, 1861.

[4] Warneck, J., *Tobabataksch-Deutsches Wörterbuch*. Batavia, 1906.

[5] Joustra, M., *Karo-Bataksch Woordenboek*. Leiden, 1907.

[6] Wilkinson, R. J., *A Malay-English Dictionary*. Singapore, 1901–1903.

[7] Winstedt, R. O., *An English-Malay Dictionary*. Singapore, n.d.

[8] Ridley, H. N., "List of Malay Plant Names." *Journ. Str. Br. Roy. As. Soc.*, No. 30. Singapore, 1897.

It will be found that many of the vernacular names recorded in the present paper are additions to the dictionary of De Clercq and Greshoff. The most interesting names, however, are those already recorded, perhaps with many variants, in a wide range of languages. The writer has made special notes of such cases, as a slight contribution to the vocabulary of Common or Original Indonesian. In doing so, the Philippine dictionary of Merrill [9] has been most serviceable as a supplement to De Clercq and Greshoff. In the field of Philippine plant names Merrill's work has been extended by the painstaking and scholarly contributions of E. E. Schneider, William H. Brown [10] and others.

In the lists that follow, A. is used as an abbreviation for the Asahan dialect, and K. for Karo. Other abbreviations will be easily understood.

The spelling of Sumatran native names follows the Dutch method. No scholar will fail to consult Dutch authorities, and since an understanding of the Dutch system is indispensable anyway, it seems wise to adopt it in dealing with languages that are generally written in it. The use of *oe* as the equivalent of *u* is the only really objectionable feature of the Dutch spelling, which is, in some respects, better than the English.

## SPECIES COLLECTED IN ASAHAN

### FILICES

BLECHNUM ORIENTALE L.; *pahoe lipan* (A.). — Silo Maradja, Bidin 131, B. & La R. 461. Used as medicine. The name is a variant of the more frequent *pakoe*, and is discussed in the Karoland list under *Microlepia platyphylla*.

[9] Merrill, E. D., *A Dictionary of the Plant Names of the Philippine Islands*. Manila, 1903.

[10] Brown, William H., *Wild Food Plants of the Philippines*. Bull. 21, Dept. Agric. and Natural Resources. Manila, 1920; West, Augustus P., and Brown, Wm. P., *Philippine Resins, Gums, Seed Oils, and Essential Oils*. Bull. 20, Dept. Agric. and Natural Resources. Manila, 1920.

These two bulletins and others in the same series contain long lists of vernacular plant names, "revised by E. E. Schneider, who is conversant with several Philippine dialects, and has taken great interest in the proper spelling of local names of Philippine plants."

Ceratopteris thalictroides (L.) Brongn.; *pahoe roesi* (A.). — Silo Maradja, Bidin 95, B. & La R. 425.

Davallia solida (Forst.) Sw.; *pahoe binggoe* (A.). — Silo Maradja, Bidin 124, B. & La R. 454.

Dryopteris sagittifolia Bl. O. Ktze.; *pakoe koening* (K.). — Boenoet, Galoengi 7, B. & La R. 7.

Loxogramme involuta Don Presl; *si marharehare* (A.). — Silo Maradja, Bidin 162, B. & La R. 492. Smoked with tobacco.

Lygodium circinnatum (Burm.) Sw.; *pahoe riboe-riboe pandjang* (A.). — Silo Maradja, Bidin 39, B. & La R. 369. Used in the rice ceremonies. (*Goenanja ramoean padi.*)

Lygodium flexuosum (L.) Sw.; *pahoe riboe-riboe* (A.). — Silo Maradja, Bidin 22, B. & La R. 352. Used in the ceremonies for securing a bountiful rice harvest.

Odontosoria chinensis (L.) J. Sm. — Bandar Pasir Mandoge, Galoengi 32, B. & La R. 30.

Polypodium longissimum Bl.; *hare-hare* (A.). — Silo Maradja, Bidin 23, B. & La R. 353. It may be presumed that the name is more or less generally applicable to any epiphyte, since in Toba *hare-hare* is the name of moss growing upon wood (*fide* Warneck) and *si morharehare* the name of an epiphyte on the sugar palm. In this list *si marharehare* (A.) will be found as the name for *Loxogramme involuta*, and De Clercq and Greshoff have *hare-hare mombang boroe* as the name for *Nepenthes gracilis*. Warneck gives *mombang boroe* as the name of an "orchid" found hanging in trees. The only common characteristic of the various plants is that all of them are epiphytes.

### LYCOPODIACEAE

Lycopodium cernuum L.; *sarang baganding* (A.). — Silo Maradja, Bidin 94, B. & La R. 424; Bandar Pasir Mandoge, Galoengi 30, B. & La R. 28. The name might be translated "snake's umbrella." *Sarang* is a nest, or a roof, or whatever will keep off rain.

SELAGINELLACEAE

SELAGINELLA SP.; *saio merah* (A.). — Silo Maradja, Bidin 33, B. & La R. 363.

SELAGINELLA SP.; *saio pais* (A.). — Silo Maradja, Bidin 144, B. & La R. 474.

SELAGINELLA SPP. — Bandar Pasir Mandoge, Galoengi 20, B. & La R. 18 and Galoengi 25, B. & La R. 23.

GRAMINEAE

ANDROPOGON SCHOENANTHUS L.; *sorei* (Asahan Mal.), *sangge-sangge* (A. and also, *fide* Warneck, Toba). — Grown in the ladangs. Lemon grass is planted, with other important ceremonial plants, as an offering to ancestral spirits, to whom it is supposed to give great satisfaction. The text of an invocation to ancestral spirits inscribed on a joint of bamboo, obtained by the writer at Silo Maradja, reads as follows:

"djaha ma ale amang hoetongon ma djoema nami di topi ni pargampoealan hinapit rodang ni soenge parlak kitangan disima djoema nami na marpandjoeloekkon taboe gerger dohot sangge-sangge dohot hapal-hapal dohot dingin-dingin dohot si hilap si panggil dohot sori mandapot dohot roedang tiga roepa ale amang na mamasai oelang didok hamoe goran ni hadatoeon borit na hoesoeratton bai boeloe na marataon ibaen ahoe na hoerang malo mambasa soerat ale amang na mamasai." The translation is about as follows: "Read, oh father! I prepare our clearing at the edge of the fishing place, confined by the swamps of the river. The garden hemmed in there is the clearing of us who plant red sugar cane, with lemon grass, with cooling herb, with cooling herb [a repetition in Malay for the sake of definiteness?], with fragrant root, the [soul-] recaller, with the indicator of fate, with three kinds of roedang [plants pleasing to spirits]. Oh father who readest this let not by you be spoken the name of the magic of sickness. I who write this green bamboo, I do it who am little skilled. Be favorable to the writing, oh father, who readest it."

This invocation is typical of many, and names several of the outstanding ceremonial plants that have to be planted in a new garden to insure the good will of the spirits. Even as they grow in the clearing they are often regarded as already having been offered to the ancestors.

Andropogon Sorghum (L.) Brot.; *dawa* (A. & K.). — Silo Maradja, Bidin 1, B. & La R. 331. Grown for the grain and found as an escape from cultivation. The series of names to which *dawa* belongs includes *djaba oere* (Batak), *djao* (Menangkabau), *djawa* (Balinese), *djĕwa wut* (Javanese), *djawaras* (Mal.), *djawe* (Dayak of S.E. Borneo.) Merrill states (*in lit.*) that the name in the Philippines is *daua*. His Dictionary gives *daua* as the Tagalog and Visayan name for another grain, namely *Setaria italica* (L.) Beauv., and, in the reduplicated form *daua-daua*, Tagalog for *Panicum crus-galli* L. The reduplication here indicates that in some respect the latter species is similar to the former. The wide distribution in varying forms shows that *dawa* is one of the general Indonesian plant names. The name may give some ground for the belief that dispersal of the several grains called *dawa* or *djawa* was from Java (= Djawa). The verbal similarity may, on the contrary, be accidental, as would perhaps be indicated by the fact that substantive *dawa* stands alone. It does not occur as an adjective modifying some other general name for grain, as one might expect if it indicated geographic origin. Van der Tuuk considered Sanskrit *dawa* to be the source of the Indonesian word. Ptolemy called Java "Iabadiu," probably from the Sanskrit Jawadwipa, meaning Barley Island. Since there is no barley in Java or Sumatra, Kern [11] suggests the better interpretation Millet Island. Of course if Java got its Hindu name from a word for grain there can be no question of the origin of a general Indonesian plant name from a geographic name to worry about. Another question arises, however, namely, Is there justification for the belief that

[11] Kern, H., in Colijn, H., *Neerlands Indie*, ed. 2, Amsterdam, 1913. (Vol. I, Hoofdstuk VI, De Godsdienst, II Het Hindoeisme.) Kern, H., *De naamsoorsprong van Java.* (Bijdr. Taal-, Land-, en Volkenkunde Ned. Ind. 3e Volgr., dl. VI. 1871.) *Verspr. Geschr.*, 5: 315–321. 's-Gravenhage, 1916.

Sanskrit influence was so early in the Archipelago as to contribute to the vocabulary properly called Common Indonesian, in the sense of antedating dialectical differentiation of the speech? The answer is certainly no, and that one must distinguish carefully between really primitive words and unusually widely distributed loan words. If Batak *dawa* is really Common Indonesian, the resemblance to a Sanskrit word for grain is probably accidental. Presumably, however, the word is a late-comer and one of the more widely diffused Sanskrit elements in the island languages.

Centotheca latifolia (Osb.) Trin.; *doehoet besan* (A.). — Silo Maradja, Bidin 60, B. & La R. 390.

Coix lachryma-Jobi L.; *sikkoroe* (A.). — This name is a variant of *singkoroe*, which is the Toba form. It is isolated, all the other recorded names being traceable to the base *djali* through simple mutations. Silo Maradja, Bidin 25, B. & La R. 355.

Digitaria consanguinea Gaudich.; *doehoet napa* (A.). — Silo Maradja, Bidin 111, B. & La R. 441. The native name means dung grass, and refers to the usual habitat of the grass, in highly manured soil. It is interesting to observe that *doehoet* is a general term for weedy grasses and grass-like weeds. No Common Indonesian term for weed has come to the attention of the writer. Apparently the conception was one that developed *pari passu* with agriculture, and was wanting among the earliest stocks of the Indonesians to spread over the Archipelago. Later migrations had a word which is represented in some form throughout the islands south of the Philippines. Toba *doehoet* is of course Karo *doekoet*. Malay and Menangkabau have *roempoet*, Sundanese, *djoekoet*, and Javanese *soeket* or rarely *doekoet*. These words all seem to be exact equivalents. The Malay word has extended to all the eastern islands of the Archipelago wherever Malay is the coastal language. As would be expected from their generic nature, *doehoet* and equivalent words must be modified to designate any particular weed. If reduplicated, the word refers to weeds of small kinds, in a vague sense, as we might say "all sorts of little weeds." De Clercq lists one hundred and seventeen kinds of *roempoet*. The exact

equivalence of Sundanese *djoekoet* and Javanese *soeket* is illustrated by a parallel nomenclature in the two languages, often with identical or equivalent specific "adjectives," for a long list of species, among which are *Panicum Crus-galli, P. auritum, P. muticum, Eleusine indica, Cynodon Dactylon, Andropogon aciculatus, Fimbristylis globulosa* and *Desmodium triflorum.* Most of the species are grasses, but sedges and even some dicotyledonous plants of more or less grass-like habit are included, just as the popular conception of "grass" in English is far wider than the scientific. Among the non-grasses called *soeket* in Javanese are *Viola serpens, Eriocaulon sp., Vandellia crustacea, Cassytha filiformis, Merremia convolvulacea, Emilia purpurea, Rubia cordifolia* and *Galium subtriflorum.*

Digitaria sanguinalis (L.) Scop.; *roempoet pandjang* (Mal.). — Silo Maradja, Bidin 70, B. & La R. 400.

Digitaria violascens Link. — Boenoet, Galoengi 58, B. & La R. 52.

Eleusine indica (L.) Gaertn.; *padang roeroes* (A.), *padang tegoeh* (K.). — Silo Maradja, Bidin 51, B. & La R. 381; Boenoet, Galoengi 70, B. & La R. 70. Used as a medicine for worms. Although *padang* generally means a grassy plain, it is in several languages a generic term for coarse grasses, several of which are used in various ceremonies. In Karo it has only the latter significance. In Gajo [12] it has both, but the former only in geographic names. In Toba both meanings are found, and in Malay, apparently, or at least in Peninsular Malay, it means only a treeless plain. Menangkabau is like Malay, but in Balinese we again find many species of grass listed as *padang* of various sorts. If, as many believe, the treeless plains of Indonesia are largely due to human agencies, the botanical meaning of *padang* is likely to be the primitive one.

Eragrostis pilosa (L.) Beauv.; *doehoet haloes* (A.), *roempoet aloes* (Mal.). — Silo Maradja, Bidin 49, B. & La R. 379.

Eragrostis unioloides (Retz.) Nees; *doehoet* (A.), *doekoet-doekoet* (K.), *roempoet* (Mal.). — Bandar Pasir Mandoge, Galoengi

[12] Hazeu, G. A. J., *Gajosch-Nederlandsch Woordenboek met Nederlandsch-Gajosch Register.* Batavia, 1907.

15, B. & La R. 15; Boenoet, Galoengi 63, B. & La R. 63. The names are of course vague, and not specific for this grass. See note under *Digitaria consanguinea*.

Gigantochloa robusta Kurz; *boeloe-boeloe* (A.). — Flowered and fruited abundantly in 1918. Boenoet, Galoengi 1, B. & La R. 1. The name given is not specific, but applicable to any large bamboo. *Boeloe* is Common Indonesian, and probably the primitive form of the word. In the East Indies are *boeloe* (Malay and Toba), *boeloeëh* (Midd. Sumatra), *boelo* (Dyak, Makassar, Sangirese), *woeloeh* (Javanese), *woeloeng* (Sundanese), *oloh* (Gajo), *lewoeo* (Nias), *awo* (Buginese), *oewa* (Boeroe Alfurese), *loeloe* (Bentenan Alfurese), *loöe* (N. E. Halmahera), *wojo* (Tomini Alfurese), *oo* (Bimanese). In Madagascar *vulu* (Malagassy) is very close to the primitive form. In the Philippines are *bulu* (Visayan, Iloco, Ibanag), *bolo* (Visayan, Tagalog, Iloco), *loob* (Visayan), *bolong* (Bicol, Visayan), *kaboloan* (Bicol), *boho* (Tagalog, Isinai, Mindanao), *boko* (Visaya), and *boo* (Tagalog). Dempwolff would append Mota *pue* to this Indonesian series.

Imperata cylindrica (L.) Beauv.; *rinon* (A.), *boenga rih* (K.). — Boenoet, Galoengi 67, B. & La R. 67. This coarse grass is the *lalang* (Mal.) of the grassy plains of the East Indies. From its prevalence and importance it might be expected to have more than one series of names, as is indeed the case. The names related to *lalang*, although more familiar, appear not to have as wide a distribution as the *rih* series, to which the Batak names belong. If the Philippine names doubtfully included in the *rih* series belong there, *rih* may be added to the Common Indonesian [13] vocabulary. Beginning in the north of Sumatra and proceeding southeastward, eastward, and northward, we have: *rih* (Karo), *ri* (Toba), *djeh* (Gajo), *eurih* (Sundanese), *re* (Sasak, Sumbawa), *eri* and *edi* (Alfurese of south Seran), *weri* (Alf. of Haroekoe), *weli* (Alf. of south Seran and Hila on Ambon), *fi*

[13] As will be obvious to readers acquainted with the scientific literature on Indonesia, the frequent allusions to Common Indonesian refer to the researches of Brandstetter, some of which have become generally available in the following English translation: "*An Introduction to Indonesian Linguistics, Being Four Essays*," by Renward Brandstetter, translated by C. O. Blagden. Asiatic Society Monographs, Vol. XV. London, 1916.

(Rotinese and "Malay" of Timor), *balili* and *ilib* (Pampangan).

Leptaspis urceolata (Roxb.) R. Br.; *sikoeris* (A.). — Silo Maradja, Bidin 44, B. & La R. 374. The name is doubtless related to Malay *kĕris* and Toba *horis*, dagger.

Oplismenus compositus (L.) Beauv.; *si rappas taloen* (A.). — Silo Maradja, Bidin 59, B. & La R. 389. The name means "seizer of abandoned clearings."

Panicum patens L.; *sihallong namboer* (A.). — Silo Maradja, Bidin 58, B. & La R. 388. The name means "dew carrier."

Panicum reptans L. (*P. prostratum* Lam.); *boeloe tano* (A.). — Silo Maradja, Bidin 50, B. & La R. 380. "Ground Bamboo."

Panicum sarmentosum Roxb.; *hombil* (A.). — Silo Maradja, Bidin 56, B. & La R. 386. Used as a medicine in bathing. (*Goenanja obat mandi.*)

Pogonatherum paniceum (Lam.) Hack.; *simpalis* (K.). — Bandar Pasir Mandoge, Galoengi 29, B. & La R. 27. The name, meaning "the averter," refers to the use of the plant in ceremonies for banishing evil spirits, bad luck, etc. In Toba a verbal form occurs in the phrase *mamalis udan*, "drive away rain." In Gajo an unidentified grass, *padang palis*, is used in the ceremonies for freeing an unfortunate person from evil influences. *Palis* in Malay signifies turning away. *Pogonatherum crinitum* is *djoekoet palijas* or *djoekoet pajijas* in Sundanese. In the Asahan dialect *Grewia acuminata* is *andor sipalis*.

Saccharum officinarum L.; *toboe* (A.). — Cultivated in the ladangs and used as a ceremonial plant, especially a variety known as *toboe gerger*, or red cane. The sugar cane has spread far, and there is more than one series of names, as might be expected. The *toboe* series is Common Indonesian and even extends beyond Indonesia to Micronesia, Melanesia and Polynesia. The Indonesian variants follow: *toboe* (Toba), *toe* (Gajo), *tebeë* or *teabeë* (Atjeh), *teboe* (Karo, Balinese, Buginese, Javanese, Malay, Timorese), *tebhoe* (Madurese), *tebaoe* (Midd. Sum.), *toeboe* (Malay of Amboina and Menado), *taboe* (Menangkabau, Makassar, Dayak of W. Borneo), *tapo* (Dayak of S.E. Borneo), *tawoe* (Endeh), *toewoe* (Sangi, Bentenan dialect of Alfurese),

*towoe* (Nias, Watoebela, Tomini dialect of Alfurese), *tewo* (Solor), *tewoe* (Dayak of S.E. Borneo), *tiwoe* (Sundanese), *tiboe* (Soemba), *deboe* (Sawoe), *doboe* (Bimanese), *tohoe* and *tehoe* (several dialects of Alfurese), *tefoe* (Rotinese, Timorese, Boeroe), *tifoe* (Boeroe), *tooe* (Gorom), *teoe* (Manggarai), and *keoe* (Kisar). In the Philippines we find Tagalog *tubo*, Visayan *tobo*, and Ibanag *tavvu*. In the New Guinea area are the abraded monosyllabic forms *tob* (Makian, Region of the Four Radjas, New Guinea), *toeb* (Region of the 4 Radjas), and *kob* (Noemfor of New Guinea), but also the bisyllabic *tou* of Mota and of the Graged of the north coast of New Guinea. The names listed above are mostly sorted from De Clercq's *Woordenboek*. Kats [14] carries the *teboe* series still further to the eastward by deriving from it the following Micronesian and Melanesian forms: *tupo* (Chamoro), *tup* (Bismarck Arch., New Britain), and *tô* (Marshall Islands). There can be little doubt that Kern [15] correctly referred Fijian *dovu* (written *ndovu* by Hale) [16] to the *teboe* or *toboe* series. The Samoan [17] *tolu* is clearly enough of the same origin. Other Polynesian languages have *to*. (Hale [17] lists *to* from Tonga, Rarotonga, Mangareva, Tahiti, Hawaii, and Nukuhiva.) This Polynesian *to* is not necessarily identical in exact line of descent with the same final form which occurs in the Micronesian speech of the Marshall Islands. However, Dempwolff [18] looks upon *to* as a loan word in the Marshall Islands speech, on the ground that in this language primitive *t* is represented by *dj*. It is therefore not inconceivably Polynesian in origin as well as form. It seems likely that monosyllabic end forms were reached

[14] Kats, J., *Het Tjamoro van Guam en Saipan vergeleken met eenige verwante talen.* The Hague, 1917.

[15] Kern, H., *De Fidji-taal vergeleken met hare verwanten in Indonesië en Polynesië* (Verbeterd en bijgewerkt). Verspreide Geschriften, Vols. IV, V. The Hague, 1916.

[16] Hale, Horatio, *United States Exploring Expedition during the Years 1838, 1839, 1840, 1841, 1842, under the Command of Charles Wilkes, U. S. N. Ethnography and Philology.* Philadelphia, 1846.

[17] Pratt, Geo., *A Grammar and Dictionary of the Samoan Language.* 3d and revised edition. London, 1893.

[18] Dempwolff, Otto, *Die Lautentsprechungen der indonesischen Lippenlaute in einigen anderen austronesischen Südseesprachen.* Beihefte zur Zeitschrift für Eingeborenen-Sprachen, 2. Berlin, 1920.

independently in New Guinea, Melanesia and Polynesia. The series of names of the sugar cane typified by *teboe* or *tebu* (which is probably very close to if not actually the original or primitive form) have been shown to be not merely Common Indonesian, but Austronesian or Malayo-Polynesian in the broadest sense.

SETARIA ITALICA (L.) Beauv.; *si marihoerihoer ni asoe* (A.). — Silo Maradja, Bidin 7, B. & La R. 337.

THEMEDA GIGANTEA (Cav.) Hack.; *sanggar* (A.). — Silo Maradja, Bidin 62, B. & La R. 392.

ZEA MAYS L.; *djagoel* and *djagoeng* (A.). — The former name is used in the formulae of ceremonies, and is interesting because it is the only recorded parallel with Javanese Krama (Doesoen) *djanggel* and Ngoko *djagoeng*. As might be expected from the late dispersal of maize in the Orient, it has no Common Indonesian name. *Djagoeng* or some simple variant is widespread indeed, being the name found throughout the Sunda Islands and the Malay Penninsula, but except as a Malay word it does not extend (at least in recognizable form) to the eastward (where there are numerous names) or into the Philippines. It may be noted that there are many varieties of *djagoeng*, some of which belong to *Andropogon Sorghum*. Furthermore, the Javanese and Sundanese names *djagowan* and *djadjagoan* for *Panicum Crus-galli* seem to be derived from *djagoeng*. The traditional Javanese chronology [19] places the introduction of maize in the year 297 Saka (= 371 A.D.) among purely legendary events, which would seem to indicate that the name *djagoeng* was formerly applied to some plant or plants other than maize, and subsequently came to be applied almost exclusively to the latter. *Andropogon Sorghum* may originally have borne the name, although this plant has also a still more general Indonesian name *dawa*. (See note under *Andropogon Sorghum*.)

CYPERACEAE

CYPERUS DISTANS L. — Boenoet, Galoengi 64, B. & La R. 64.

CYPERUS ELEGANS Link; *si marpandanpandan* (A.), *ria-ria*

[19] Raffles, Thomas Stamford, *The History of Java*. London, 1817. (See chronology in Vol. II, p. 232.)

*pandan* (A.). — Silo Maradja, Bidin 46 and 52, B. & La R. 376 and 382. The name *pandan* is generally used for any sedge or monocotyledonous plant that can be used in mat-weaving. Regarding the name *ria-ria* see the note under *Rhynchospora corymbosa*.

Fimbristylis annua R. & S. var. diphylla (Retz.) Kükenth. — Boenoet, Galoengi 62, B. & La R. 62.

Fimbristylis miliacea Vahl. — Boenoet, Galoengi 66, B. & La R. 66.

Kyllinga brevifolia Rottb. — Boenoet, Galoengi 69, B. & La R. 69.

Kyllinga monocephala Rottb.; *andor si tiga boeloeng* (A.). — Silo Maradja, Bidin 146, B. & La R. 476.

Mariscus Sieberianus S. & Z.; *padang sila* (A.). — Silo Maradja, Bidin 47, B. & La R. 377. Used as medicine for worms.

Rhynchospora corymbosa (L.) Britton; *ria-ria* (A.). — Silo Maradja, Bidin 20, B. & La R. 350. In Van der Tuuk's *Woordenboek* (p. 452) *rija-rija* is given as the Toba name of a certain kind of grass worn in the hair as a sign of victory, and also to signify a declaration of war. Since the base *ria* has the meaning "gathering together," the name probably points to the plant having been worn by messengers or heralds sent to call people from the distant *ladangs* to an assembly.

### PALMAE

Areca Catechu L.; *pining* (A.). — As everywhere else in Malaya, the betel-nut palm plays an important part in native economy. The inflorescence is used in many ceremonies and is one of the class of ceremonial plants (or parts of plants) known as *roedang* (A.).

Arenga saccharifera Labill.; *bagot* (A.), *si lambe boeloeng* (A. *hata andoeng*, the special vocabulary of mourning). — Treated at length in a former article.[20]

[20] Bartlett, H. H., "The Manufacture of Sugar from *Arenga saccharifera* in Asahan, on the East Coast of Sumatra," *Ann. Rep. Mich. Acad. Sci.*, 21: 155–169. 1920.

Cocos NUCIFERA L.; *halambir* (A.). — There is no plant whose vernacular nomenclature is more interesting than that of the coco palm. There are several series of apparently unrelated names. In the Batak lands the widespread Malayo-Polynesian series, typified by *njijoer* (Mal.) and *niu* (Samoan), is present, but does not prevail. The word of the Asahan dialect, *halambir*, is a variant in a second series, including *harambir* (Toba), *kělambir* (Mal.), *karambil* (Mal.), *krambel* (Gajo), *krambil* (Jav Ngoko), *karambië* (Menangkabau) and *ketjambil* (Tegal-Jav.). This series is confined, apparently, to Sumatra, Java, and the Peninsula, and may be judged to have come into use in the Archipelago very much later than the *njijoer* series. A third series, typified by Malay *kelapa*, includes the Krama Javanese *klapa*, which we may not unreasonably conclude to be later than the *halambir* series, since Javanese Njoko is *krambil*. The common speech, in Java at least, is probably older than the largely artificial Krama with its borrowed words. Among the earliest Malayo-Polynesian migrations from Asia were the *njijoer* speakers, who left their language throughout Indonesia, Micronesia and Polynesia. The *karambir* speakers partially displaced *njijoer* within the extent of the closely related Javanese-Sumatran language group, and came very much later. The diffusion of the word *kelapa* and its variants seems to have come about largely through Malay traders and not through folk migrations. The series of names to which the English coco is nearest centers in the Celebes, and includes *kaloekoe* (Bugi, Boeton, Makassar), the reduplicated monosyllable *koekoe* with infix *al*, *kajoekoe* (Tomini-Alfurese), *koekoer* and *kokoer* (Sumba), with other less obvious variants represented as far west as Sumatra and the Mentawei Islands. The origin of the word coco in English and other European languages has been considerably discussed. The *Oxford Dictionary* (Murray himself elaborated the letter C) has the following: "The early writers from Cosmas 545 to the 15th century knew it only as the Indian nut or nut of India; *coquos* (plural) is quoted first from the Roteiro de Vasco da Gama (Portuguese 1498–1499); Barbosa 1516 has (Pg.) *quoquos;* Pigafetta 1519 has (It.) *coche* pl. of *coca;*

Oviedo 1526, Barros 1553, Garcia 1563, and Acosta 1578 have *coco;* Correa *coquo.* The Portuguese and Spanish authors of the 16th century agree in identifying the word with Pg. and Sp. *coco* 'grinning face, grin, grimace,' also 'bugbear, scare crow,' cognate with *cocar* 'to grin, make a grimace'; the name being said to refer to the face-like appearance of the base of the shell, with its three holes. Historical evidence favors the European origin of the name, for there is nothing similar in any of the languages of India, where the Portuguese first found the fruit; and indeed Barbosa, Barros, and Garcia, in mentioning the Malayalam name *tenga* and Canarese *narle* expressly say '*we* call these fruits *quoquos,*' '*our people* have given it the name of *coco,*' 'that which we call *coco* and the Malabars *temga.*'" To the contrary, the revised *Century Dictionary* says: "The resemblance of the Sp. Pg. name to Sp. Pg. *coco,* a word used to frighten children, a bugbear, is probably accidental." By way of comment on the quotations one may point to the existence of words very similar to coco in parts of the Indian Archipelago visited by the Portuguese as early as 1511, and, as will be pointed out, not impossibly established there by Arab traders whose influence and trade extended all the way along the coast of southern Asia and down the east coast of Africa. Vasco da Gama may have had the word from the Arabs, whose trade routes he followed. There is, therefore, no reason to suppose the word coco to be of Portuguese origin because it fails to appear in Malayalam or Cannarese. Now let us quote the Pliny of the Orient, whose old-fashioned Dutch would perhaps be less intelligible than Burman's translation:[21] "Fructus autem Latine dicitur Nux indica, et cocus, male apud Scaligerem . . . coccus; Portugallis coquo, et coco, juxta imaginem, uti Linschotenus, et alii plures putant, faciei Cercopitheci, quam tria superiora putaminis orificia repraesentant; meo vero judicio verior ac certior vocis origo invenienda est; plures enim nationes quibus hic fructus est notus nucem appellant, sic dicitur Arabice Gauzos-Indi vel Geuzoz Indi h. e. Nux Indica quod per inter-

[21] Rumphius, G. A., *Herbarium Amboinense,* I, p. 7. Amsterdam, 1741.

pretes Avincennae . . . corruptum est in Jausi Alindi, et, quod pejus Jansi Alindi, Turcis Cocʼk-Indi eadem significatione, unde sine dubio Aethiopes Africani eorum vicini Hispani, ac Portugalli Coquo deflexerunt." Nothing seems to the writer more likely than that Arab traders might have introduced their own name for the coconut, known to them for centuries before the Portuguese era in the Orient, to the people among whom they went. Furthermore, since the phonetic system of Indonesian does not admit the harsh sounds of Arabic, some such simplification might have taken place as that resulting in coco. This the Portuguese might have seized upon, from among many names for coco that they certainly heard, because of its coincidence with their name for monkey face. As for the form *kokoer*, reported for Sumba, it is practically identical with *coker*, an alternative name of coco preferred in commercial jargon because of its entire distinctness from cacao. That the Indonesian names are not modern adaptations of the Europeanized coco is shown by the fact that Rumphius cites[21] *igo* (Ternate), *calucu* (Makassar) and *lalucco* (Boeton). Although the part of his work dealing with the palms was edited and published in 1741 it was composed before 1690 in Amboina.

Daemonorops oblongus Mart.; *hotang* (A.), *kĕtang* or *kĕttang* (K.), *rotan* (Mal.). — Bandar Pasir Mandoge, Galoengi 23, B. & La R. 21.

ARACEAE

Alocasia macrorrhiza Schott; *birah* (A.). — Commonly grown in the ladangs. The very large leaves are used as umbrellas. The name is traceable with only slight variations through most of the languages of the Archipelago, including *birah* (Mal.), *biha* (Bandjarese, Sundanese, Sangir), *bijah* (Bali), *bijo* (Nias), *bira* (Toba, Gorom, Madoera, Makassar), *hila* (Ambon-Alfurese), *kiha* (Halmahera, Menado, Ternate), *lawira* (Bugi), *wija* (Bimanese) and in Madagascar *viha* (Malagassy). The Philippine names belong to the same series, the most common form being *biga*, but *bira* also occurs in Ilocos Norte, Cogayan and Pangasinan. (See Brown, *l.c.*, f. n. 11.) *Bira* is

probably the primitive Common Indonesian word. It would be especially interesting to find it still in Continental Asia, if Lushai (Lakher) *bia* should prove to be [22] the same. Although only doubtfully extending beyond Indonesia into Asia, it certainly extends far into another speech area eastward, although it has not been traced far enough to be claimed with certainty as Malayo-Polynesian. Safford [23] says: "The Philippine name for Alocasia (biga), which becomes piga in Guam, reappears in Fiji as via. The etymological identity of these words is undoubted, for the changes which the consonants undergo follow the same law in many other words." Dempwolff [18] gives Fijian *via* as the easternmost member of the *bira* series, and the Polynesian equivalent has not yet been located. In view of the general agreement of the Indonesian names for Alocasia, it is strange to find that Javanese, Balinese and Sundanese have a second word, *sente*. The latter name is isolated unless it is cognate with *soenti* (Javanese) and *sonte* (Madurese), which apply to *Zingiber gramineum* Noronha. Sometimes distantly related plants bear the same name because of some similar use or association, but it is more likely that these words are not etymologically related.

Scindapsus or Raphidophora; *sarindan siala* (A.). — Silo Maradja, Bidin 133, B. & La R. 463. Used as food.

COMMELINACEAE

Commelina nudiflora L.; *těngkoea* (K.) — Boenoet, Galoengi 60, B. & La R. 60. There is great discrepancy between this identification and Joustra's definition of *těngkoewa, sitěngkoewa*, "naam v. e. boom, waarvan men een sterk vruchtafdrijvend middel weet te bereiden."

LILIACEAE

Dianella odorata Bl.; *boenga raja* (A.). — Silo Maradja, Bidin 164, B. & La R. 494. Used as medicine.

[22] Lorrain, H. J., and Savidge, F. W., *Grammar and Dictionary of the Lushai Language*. Shillong, 1898.

[23] Safford, W. E., *The Useful Plants of Guam*. Cont. U. S. Nat. Herb., IX, Washington, 1905. See p. 153.

Pleomele (Dracaena) Cantleyi N. E. Br. (?). — Silo Maradja, Bidin 161, B. & La R. 491.

Smilax sp.; *damar-damar* (A.). — Silo Maradja, Bidin 71, B. & La R. 401. *Damar* is the Malay and Batak name for the resin from the coniferous genus Dammara. The identity of this name with the Asahan name for a small non-resinous vine is probably mere coincidence. De Clercq lists various species of smilax as *tjanar* (Sundanese), *banar* (Madurese), *banara* (Balinese) and *bana* (Buginese). To this series of names *damar-damar* would seem to belong. That it has not been incorrectly recorded is shown by Warneck's Toba dictionary, which lists "*damar-damar*, eine Schlingpflanze."

Smilax sp.; *damar-damar aloes* (A.). — Silo Maradja, Bidin 72, B. & La R. 402.

Taetsia (Cordyline) fruticosa (L.) Merr.; *silindjoeang* (A.). — Silo Maradja, Bidin 80, B. & La R. 410. Used as a medicine, in certain ceremonies, and in the preparation of devices for preventing the approach of evil spirits. According to De Clercq these uses are quite general in the Archipelago, for the species of Cordyline in general, and doubtless account for a group of etymologically similar names which have not been shown to extend far enough to be considered Common Indonesion, but are widespread in the western area south of the Philippines. They are: *djoewang-djoewang*, *djedjoewang* and *lendjoewang* (Mal.), *bak djoewang* (Atjeh), *lindjoewang* (Toba and Menangkabau), *silindjoewang* (Toba and A.), *sendjoewang* (Mal.), *randjoewang* (Mal. W. Borneo), *rendjoewang* (Dayak), *pendjeloelang* (Mid. Sumatra), *panjaoerĕng* (Buginese), *andjiloewang* (Menangkabau), *anderoewang* (Lampong), *handjoewang* (Sundanese), *kalindjoehang* (Karo), *handwang* (Balinese), *andong* (Balinese and Javanese) and *endong* (Javanese).

### AMARYLLIDACEAE

Curculigo latifolia Dry. var. glabrescens Ridl.; *soekkit* (A.). — Silo Maradja, Bidin 132, B. & La R. 462. In Toba, *soengkit*. The names in other languages for *Curculigo spp.* are

distinct, except possibly *tjangkok* (Sundanese) and *ngangkoeh* (Javanese).

Belamcanda sp.; *sihilap* (A.) — Silo Maradja, Bidin 143, B. & La R. 472. Planted in the ladangs and used in rice planting and harvesting ceremonies. Warneck describes *sihilap* (Toba) as a reed-like plant of which the aromatic root is mixed with tobacco.

ZINGIBERACEAE

Alpinia sp.; *halawas* (A.). — Silo Maradja, Bidin 117, B. & La R. 447. The rhizome is used for food. The name in various forms is Common Indonesian. The original word may have been *langkawas* or *langkĕwas*. In the Batak languages the primitive form gave *loengkoewas* (Dairi); by metathesis *halawas* (Toba, in which initial *k* occurs only in Malay loan words), and, by condensation of the latter, *halas*, (Toba). Other variants are *langkoeëuëh* and the shortened form *koeëh* (Atjeh), *lakoeë* (Nias), *lankoewe* (Menangkabau), *lengkoewas* (Mal.), *lingkewas* (Batavia Mal.), *lingkoewas* (Minahasa, Bantik dialect), *lintjoewas* (Minahasa, Toöempakĕwa dialect), *langkoewas* (Dayak of S.E. Borneo, Mal. Molucca, Rotinese), *lawas* (Lampong), *laos* (Javanese, Madurese, Sasak), *lahwas* (Balinese), *langkoewasa* (Makassar), *langkowase* (Boeroe Alfurese), *laoekase* and *lakoewase* (S. Seran, — a case of metathesis), *laäwase* (S. Seran), *lakwase* (W. Seran), *latawase* (Alf. of Noesa Laoet), and *likoe* (Buginese). The Philippines have *langkauas* as the most general name of *Alpinia pyramidata*, with *langkuas* in Bisaya, Manobo, Banuaon and Mangguangan. The evidence that the name is Common Indonesian is overwhelming, and especially interesting linguistically because the primitive form is trisyllabic rather than bisyllabic.

Alpinia sp. (?); *sitanggis* (A.). — Silo Maradja, Bidin 163, B. & La R. 493.

Curcuma zedoaria Rosc.; *hoenik* (A.). — Silo Maradja, Bidin 121, B. & La R. 451. The ceremonial uses of this species and *C. longa* are very numerous and widespread. Therefore, as would be expected, the names are likewise not local, but extend

widely. There is more than one series, but only the one to which *hoenik* belongs appears to be Common Indonesian. It is fundamentally the same word as the Malay *koening*, "yellow," the roots of Curcuma providing the most generally used yellow pigment. In some of the languages that have used the primitive word for yellow as the plant name, there is a totally different word for the color, as, for example, *gorsing* (Toba) and *gersing* (Karo). The *koenik* series, applying to Curcuma generically, follows: *koenik* (Menangkabau, Rotinese), *hoenik* (Toba), *koening* (Karo & Dairi), *koneng* (Sundanese), *hoening* ("Batak"), *koenjet* (Atjeh), *koenjit* (Malay and Balinese), *koenjik* (Menangkabau and Sasak), *koenji* (Makassar), *konjek* (Madurese), *koenjir* (Lampong and Sundanese), *koenir* (Javanese, Balinese, several Alfurese dialects), *koendjir* (Lampong), *koenai* (Menangkabau), *koeni* (several Alfurese dialects), *hoeni* (Bimanese), *koendidi* (Bantik dialect of Alfurese), *hoekim* (Timor), *oendre* (Nias), *oenji* and *onji* (Buginese), *oenin* (Alfurese of Haroekoe and S. Seran; Gorom), *oenino* (Amboina). In the Philippines the series is not so well represented, but the two names recorded by West and Brown (*l.c.*) are very satisfactory: *kunig* (Ilocos Sur, Cagayan) and *koniko* (Bontoc). The primitive Indonesian word would appear to have been *koenik* or *koening*. As a plant name it is Common Indonesian.

Globba sp.; *siala rodang* (A.). — Silo Maradja, Bidin 147, B. & La R. 477. Used for food. The name means river-swamp *siala*. The latter word is related to Malay *halia* and *alia*, generally applied to *Globba spp.*

Zingiber *cf.* zerumbet Sm.; *lappiang* (*A.*). — Silo Maradja, Bidin 112, B. & La R. 442. Warneck defines Toba *lampiang* as "eine lilienartige Pflanze."

Zingiberaceae indet.: (1) *palang* or *boenga palang* (A.), *kentjong* (Mal.). Ria Santun. A very tall species with fertile stems three or four feet high and pink inflorescence; (2) *siala* or *boenga siala* (A.), *tjekkala* (K.), *kentjong* (Mal.), a smaller species with acaulescent, star-shaped, scarlet inflorescences. Ria Santun; (3) *siala ngoengoe* (A. and Simeloengoen), a plant with fertile stems about two feet high. The cylindrical inflorescence

is pink and green, or flesh-colored, and the rounded spatulate bracts with upturned rims are usually full of rain-water. Seen in Asahan, and photographed at Bahal Batoe, Tanah Djawa, Simeloengoen.

ORCHIDACEAE

Calanthe veratrifolia R. Br.; *goeroe ni hambeng* (A.), *singkoet* (K.). — Silo Maradja, Bidin 40 *bis*, B. & La R. 370 *bis*. Bandar Pasir Mandoge, Galoengi 22, B. & La R. 20.

Habenaria sp.; *goeroe ni hambeng* (A.). — Silo Maradja, Bidin 40, B. & La R. 370.

Gen. & sp. indet.; *oendalangen* (A.). — A cordate-leaved, fleshy, climbing plant with pink flowers and elongated fruit. Bandar Pasir Mandoge.

PIPERACEAE

Piper arborescens Roxb. (*P. miniatum* Bl.); *losi* (A.). — Silo Maradja, Bidin 138, B. & La R. 468.

Piper caninum Bl. var.; *siangir tombak* (A.). — Silo Maradja, Bidin 17, B. & La R. 347.

Piper sp.; *baroti* (A.). — Silo Maradja, Bidin 41, B. & La R. 371.

Piper sp.; *andor siangir* (A.). — Silo Maradja, Bidin 139, B. & La R. 469.

ULMACEAE

Trema orientalis (L.) Bl.; *hanaë* (A.), *nderroeng* (K.). — Silo Maradja, Bidin 153, B. & La R. 483; Boenoet, Galoengi 13, B. & La R. 13.

MORACEAE

Artocarpus champeden (Lour.) Spreng.; *djollama so begoe* (A.). — Silo Maradja, Bidin 113, B. & La R. 443. The name recorded is unique and has the general aspect of belonging to the special *hata andoeng* (language of mourning). (In ordinary speech *djolma* would not be expanded to *djollama*.) It means "human not ghost." The specific name "champeden" is derived

from a series of names widely distributed: *tjempedak* (Mal.), *tjimpedok* and *tjempeudak* (Atjeh), *tjampedok* (Javanese and Sundanese), *tjampada* (Midd. Sumatra and Makassar), *tjampeda* (Buginese), *tjepedak* (Javanese), *tjapedak* (Bengkoelen Mal.), *tjoebadak* (Menangkabau), *soebodak* and *sibodak* (Toba), *tjomedak* (Madurese), *tembedak* (Bengkoelen Mal.), *tamedak* (Midd. Sumatra), *temedak* (Koeboe), *tiwadak* (Bandjermasin Mal.), *tewelak* (Watoebela), and *toewada* (N.E. Halmahera, Dyak, Ternate). Loureiro (*Flora Cochinchinensis*) wrote: "*Champeden vocatur a populis Malaiis circa fretum Malaccense habitantibus.*"

Artocarpus integra (Thunb.) Merr.; *nakka* (A.). — Silo Maradja, Bidin 159, B. & La R. 489. The jak fruit is of course used for food. The name is Common Indonesian although there are alternative or substitute words in a few languages. In Atjehnese, for example, the usual *nangka* is replaced by *panah* or *panas*, which extends to Toba in the form *pinasa* and to Buginese as *panasa*. The *nangka* series is: *nangka* (Karo, Gajo, Mal., Sundanese, Madurese, Kangejan, Balinese, Dayak of S.E. Borneo, and Minahasa Alfurese), *mangka* and *angka* (Minahasa Alfurese), *nangga* (Bimanese), *langge* (Gorontalese), *naka* (several Alfurese dialects), *kanakane* (Asiloeloe Alfurese), *anaäne* (Hila Alfurese), *nakaä* (Seran), *anaä* (Haroekoe Alfurese), *naa* (Nias), *anaal* (Alfurese of Noesa Laoet and Saparoea). The form *nangka* (spelled *nangca*) is the usual one in the Philippine languages, as, for example, Tagalog and Bisaya, but other forms occur also, as *nanka* and *lanka* (Tagalog) and *langka* (Ilocano). It is interesting to observe here, as in many other cases, that the primitive Common Indonesian word, generally preserved in such languages as Karo, undergoes drastic mutation in the eastern islands, approaching New Guinea, but appears in the original form in the Philippines. The inference may perhaps be drawn that except for small weak groups, such as the negritoes, the Indonesians found the Philippines uninhabited, and their language suffered little modification through racial intermingling, whereas the populations toward New Guinea were dense and vigorous, contributing blood and tongue equally to the fusion of races known as the Alfurese.

Ficus Benjamina L.; *baringin* (A.). — Planted, especially at sacred places. The area through which the vernacular name *waringin, baringin,* or some derivative is used probably indicates the extent of direct Hindu influence in the Archipelago.

Ficus diversifolia Bl. var.; *boenga tanaman* (A.). — Silo Maradja, Bidin 142, B. & La R. 472. Used for ornament and adornment. (*Goenanja perhiasan.*)

Ficus trematocarpa Miq.; *bakkal* (A.). — Silo Maradja, Bidin 78, B. & La R. 408. Smoked with opium. (*Goenanja isap sama tjandoe.*) The equivalent Toba word is *bangkal,* which Warneck has as *timbaho bangkal,* "eine Bataksche Sort Tabak."

URTICACEAE

Boehmeria nivea (L.) Gaudich.; *hori* (A.). — Silo Maradja, Bidin 27, B. & La R. 357. A source of fiber for fish lines (*tali pantjing*).

LORANTHACEAE

Loranthus ferrugineus Roxb.; *soerindan* (K.). — Boenoet, Galoengi 10, B. & La R. 10.

POLYGONACEAE

Antigonon leptopus H. & A.; *riang-riang* (A.). — Silo Maradja, Bidin 90, B. & La R. 420. Used as medicine.

Polygonum barbatum L.; *toeba paia* (K.). — Boenoet, Galoengi 56, B. & La R. 50.

AMARANTHACEAE

Aerua lanata (L.) Juss.; *si pira-pira* (A.). — Silo Maradja, Bidin 140, B. & La R. 470.

Alternanthera sessilis (L.) R. Br.; *sipira* (A.). — Silo Maradja, Bidin 32, B. & La R. 362.

Amaranthus gangeticus L.; *siaroem* (A.). — Silo Maradja, Bidin 86, B. & La R. 416. Used as a pot herb.

Amaranthus viridis L.; *bajam* (A. & Mal.). — Silo Maradja, Bidin 26, B. & La R. 356. De Clercq gives *aroem* as the Batak

name of this species also. There are two chief series of names for *Amaranthus spp.*, both Common Indonesian. They are the *aroem* series and the *bajam* series. The former is: *aroem* or *sijaroem* (Karo and Toba), *si haobwoem* (Loeboe), *haroem* (Dayak), *ajoem*, *hajoem* and *pajoem* (Lampong), *aroen* (Sika), *harum* (Bisaya), *halom* (Tagalog and Bisaya), *halon* (Tagalog). The latter includes: *bajam* (Mal., Atjehnese, Menangkabau, Sampit dialect of Dayak), *böjöm* (Gajo), *bajem* (Jav., Sundanese, Balinese), *bajang* (Mal. Molucca), *baja* (Mal. Menado, Ternate), *bawa* (Bantik dialect of Alfurese), *wawa* (Bentenan dialect of Alfurese), *bauan* (Bontoc), *bayang-bayang* (Bisaya).

Celosia argentea L.; *roedang gerger* or *roedang na gerger* (A.). — Silo Maradja, Bidin 67, B. & La R. 397. One of the plants used in nearly all ceremonies, this one especially in the offerings to protective spirits.

Celosia cristata L. var.; *soeroengan* (A.). — Silo Maradja, Bidin 5, B. & La R. 335. Another ceremonial plant, the use of which will be referred to in a later paper.

AIZOACEAE

Mollugo pentaphylla L.; *palia onggang* (A.), *boeloeng-boeloeng tawar* (K.). — Silo Maradja, Bidin 127, B. & La R. 457; Boenoet, Galoengi 65, B. & La R. 65. Used as medicine.

PORTULACACEAE

Portulaca oleracea L.; *silobar pinggan*, (A.). — Silo Maradja, Bidin 48, B. & La R. 378. Used as medicine for asthma, etc. (*Goenanja obat penjakit dada.*)

ANONACEAE

Desmos (Unona) chinensis Lour.; *losoe* (A.). — Silo Maradja, Bidin 135, B. & La R. 465.

LAURACEAE

Neolitsea sp.; *djoeng-djoeng boehit* (A.). — Silo Maradja,

Bidin 109, B. & La R. 439. Used in the ceremonies for securing a rice crop. (*Goenanja ramoewan mengambil padi.*)

HERNANDIACEAE

Illigera dasyphylla Miq.; *andor silo* (A.). — Silo Maradja, Bidin 98, B. & La R. 428.

CRUCIFERAE

Brassica juncea Coss.; *djoeragi* (A.). — Silo Maradja, Bidin 8, B. & La R. 338. Used for greens.

CRASSULACEAE

Bryophyllum calycinum Salisb.; *dingin-dingin* (A. (?) and Mal.). — Planted in the ladangs and used in the rice ceremonies. (See De Clercq, p. 186, for similar use in Middle Sumatra.)

Bryophyllum sp.; *hapal-hapal* (A.). — Silo Maradja. Used in the rice ceremonies.

PITTOSPORACEAE

Pittosporum ferrugineum Ait.; *djaroem-djaroem* and *djaroem-djaroem aloes.* (A.). — Silo Maradja, Bidin 103, B. & La R. 433 and Bidin 123, B. & La R. 453.

LEGUMINOSAE

Cassia alata L.; *galinggang* (A.). — Silo Maradja, Bidin 100, B. & La R. 430. Used as medicine.

Crotalaria Saltiana Andr.; *inggir-inggir* (K.). — Boenoet, Galoengi 11, B. & La R. 11.

Dalbergia pinnata (Lour.) Prain; *simarpalia* (A.). — Silo Maradja, Bidin 16, B. & La R. 346.

Desmodium gangeticum DC.; *samak-samak* (A.). — Silo Maradja, Bidin 4, B. & La R. 334.

Leucena glauca Benth.; *palia djawa* (A.). — Silo Maradja, Bidin 92, B. & La R. 422. Used for food.

Mimosa invisa Mart.; *si mardoeridoeri* (A.). — Silo Maradja, Bidin 64, B. & La R. 394.

Phaseolus aureus Roxb.; *katjang risi* (A.). — Silo Maradja, Bidin 102, B. & La R. 432. Used for food.

Pithecolobium jiringa (Jack) Prain; *djoring* (A.). — Silo Maradja, Bidin 87, B. & La R. 417.

Psophocarpus tetragonolobus DC.; *lope* (A.). — Silo Maradja, Bidin 36, B. & La R. 366. A food plant.

Uraria crinita (L.) Desv.; *sibola* (A.). — Silo Maradja, Bidin 141, B. & La R. 471. Used for food.

Vigna sinensis (L.) Savi; *hadio* (A.). — Silo Maradja, Bidin 101, B. & La R. 431.

OXALIDACEAE

Averrhoa Carambola L.; *balingbing* (A.). — Silo Maradja, Bidin 34, B. & La R. 364. The name *balingbing* is probably preserved in its primitive form in Toba, since it appears to be a reduplicated monosyllable with infix *al.* With only slight modifications it runs through Malay, Karo, Toba, Menangkabau, Javanese, Sundanese, Madurese and Balinese. Gorontalese has *balimbi* and some of the Alfurese dialects *balibi.* In other languages it has suffered several interesting mutations and abrasions. Among them are *malimbi* (Nias), *limbi* (Bimanese) and *libi* (Sawoe). In Atjehnese there is the strange but recognizable *thlimeng* and the still further reduced *limeng.* The Sundanese *tjalingtjing* points to the origin of Buginese *tjalene.* Some of these final derivatives would be quite unrecognizable were it not for the persistence of intermediates. The general name in the Philippines is *balimbing,* and the series is therefore Common Indonesian. The word *balingbing* refers to the shape of the angled fruit, and applies in Malay not only to Averrhoa, but also to Connaropsis and Dapania in the Geraniaceae. In Toba at least three fruits are known generically as *balingbing.*

Biophytum sensitivum DC.; *sihirpoet* (A.). — Silo Maradja, Bidin 93, B. & La R. 423. Used as medicine.

LINACEAE

Roucheria Griffithiana Planch.; *takkolan* (A.). — Silo Maradja, Bidin 65, B. & La R. 395.

RUTACEAE

Micromelum pubescens Bl.; *sisoksok* and *simarbakkosbakkos* (A.). — Silo Maradja, Bidin 91 and 128, B. & La R. 421 and 458. Bandar Pasir Mandoge, Galoengi 34, B. & La R. 31. Used as a medicine for fever.

MELIACEAE

Aphanomyxis sumatrana Miq. — Bandar Pasir Mandoge, Galoengi 27, B. & La R. 25.

EUPHORBIACEAE

Acalypha hispida Burm. f.; *marihoerihoer* (A.). — Silo Maradja, Bidin 42, B. & La R. 372.

Alchornea sp. — Boenoet, Galoengi 49, B. & La R. 43.

Antidesma cuspidatum Muell.; *palse-palse* (A.). — Silo Maradja, Bidin 24, B. & La R. 354.

Breynia racemosa Muell.; *sitopoe* (A.). — Silo Maradja, Bidin 68, B. & La R. 398. A food plant.

Bridelia tomentosa Bl.; *samodja* (A.). — Silo Maradja, Bidin 28, B. & La R. 358. Used as medicine. (*Goenanja obat darah babi.*)

Cleistanthus myrianthus Kurz. — Boenoet, Galoengi 8, B. & La R. 8.

Claoxylon polot (Burm. f.) Merr.; *si nimnim* (A.). — Silo Maradja, Bidin 45, B. & La R. 375. Used for medicine.

Euphorbia hirta L.; *si marbagot-bagot* (A.), *teriktik* (K.). — Silo Maradja, Bidin 114, B. & La R. 444; Boenoet, Galoengi 61, B. & La R. 61. Used as medicine for children's eye disorders. (*Goenanja obat boedak sakit mata.*)

Homalanthus populneus Pax; *sindoelpak* (A.). — Silo Maradja, Bidin 88, B. & La R. 418.

Macaranga javanica Bl.; *simartoelan* (A.). — Silo Maradja, Bidin 37, B. & La R. 367.

Macaranga tanarius Muell.; *mampoe* (A.) and *nangkat-nangkat* (K.). — Silo Maradja, Bidin 85, B. & La R. 415; Boe-

noet, Galoengi 48, B. & La R. 42. The bark is used for making food containers.

MALLOTUS ALBUS Muell.-Arg. (?); *sitarak* (A.). — Silo Maradja, Bidin 84, B. & La R. 414; Boenoet, Galoengi 14, B. & La R. 14. Used for making food receptacles.

MALLOTUS FLORIBUNDUS Muell. — Boenoet, Galoengi 9, B. & La R. 9.

MALLOTUS PHILIPPINENSIS Muell.; *toeba sirah* (A.). — Bandar Pasir Mandoge, Galoengi 16, B. & La R. 16. *Toeba* is a Common Indonesian plant name, applying to all plants used as fish poisons. Peninsular Malayan *tuba* is *Derris elliptica*,[24] but in the islands the name is generally applied to a variety of poisonous Euphorbiaceae which are used for the same purpose. Without regard to specific application, the East Indian names are as follows: *toeba* (Balinese, Toba, Karo, Javanese, Malay), *tobha* (Madurese), *toebai*, *toebe*, and *toewe* (Dayak), *toebo* (Menangkabau), *toepo* (Alfurese, N.E. Halmahera), *toefa* (Alfurese, Boeroe), *toela-toela*, (Alfur., Minahasa), *doewa* (Bimanese), *toewa* (Bugi, Makassar, Sangirese, Sundanese), *toeva* (Nias). The primitive form *tuba* is general in the Philippines (Tagalog, Visayan, Pampangan) and there are also such variants as *tubang* (Tagalog) and *tafu* (Cagayan). Outside of Indonesia are the cognate forms *tuwa* or *nduva* (Fiji) and *tua* (Mota).

PHYLLANTHUS URINARIA L.; *si margalagala* (A.). — Silo Maradja, Bidin 126, B. & La R. 456. Used for medicine.

PHYLLANTHUS SP.; *sereme* (K.). — Boenoet, Galoengi 50, B. & La R. 44.

### BALSAMINACEAE

IMPATIENS BALSAMEA L.; *katjar* (K.). — Boenoet, Galoengi 68, B. & La R. 68. See note in Karoland list.

### RHAMNACEAE

ZIZYPHUS CALOPHYLLA Wall.; *sisilon ni boet* (A.). — Silo Maradja, Bidin 77, B. & La R. 407.

[24] Gimlette, J. D., *Malay Poisons and Charm Cures*. London, 1915.

VITACEAE

Ampelocissus ochracea (T. & B.) Merr.; *poerba djolma* (A.). — Silo Maradja, Bidin 156, B. & La R. 486.

Cissus pyrrodasys Miq. — Boenoet, Galoengi 55, B. & La R. 49.

Columella (Cayratia) japonica (S. & Z.) var.; *raba-raba* (A.). — Silo Maradja, Bidin 75, B. & La R. 405; Bandar Poelo, Galoengi 45, B. & La R. 40. Used as medicine for intermittent fevers, malaria, etc.

Leea aequata L.; *asosoran* (A.). — Silo Maradja, Bidin 55, B. & La R. 385. Used as medicine for boils.

Leea indica (Burm. f.) Merr.; *pĕrbentjil* (K.). — Boenoet, Galoengi 54, B. & La R. 48.

Tetrastigma lanceolarium Planch.; *andor si rekrek* (A.). — Silo Maradja, Bidin 148, B. & La R. 478. A food plant.

TILIACEAE

Grewia acuminata Juss.; *andor sipalis* (A.). — Silo Maradja, Bidin 119, B. & La R. 449; Bandar Poelo, Galoengi 39, B. & La R. 34. Used as medicine. See note under *Pogonatherum paniceum*.

Grewia paniculata Roxb. — Bandar Poelo, Galoengi 36, B. & La R. 33.

MALVACEAE

Hibiscus rosa-sinensis L.; *hatoenggal* (A.). — Silo Maradja, Bidin 165, B. & La R. 495. Used as medicine.

Hibiscus surattensis L.; *igar-igar* (A.). — Silo Maradja, Bidin 96, B. & La R. 426. Used to make an acid condiment. (*Goenanja bikin asam.*)

Sida corylifolia Wall.; *tamba toba toea* (A.). — Silo Maradja, Bidin 9, B. & La R. 339. Used as medicine.

Sida rhombifolia L.; *si bagoere* (A.), *bĕras-bĕras* (K.). — Silo Maradja, Bidin 150, B. & La R. 480; Boenoet, Galoengi 6, B. & La R. 6.

Urena lobata L.; *sampeloeloet* (K.). — Boenoet, Galoengi 3, B. & La R. 3.

Urena lobata var. scabriuscula (DC.) A. Gray; *pidjer keling* (K.). — Bandar Pasir Mandoge, Galoengi 21, B. & La R. 19.

Wissadula periplocifolia L.; *boeloeng-boeloeng pagar* (A.). — Silo Maradja, Bidin 10, B. & La R. 340. Used for medicine.

STERCULIACEAE

Commersonia Bartramea (L.) Merr.; *longa-longa* (A.). — Silo Maradja, Bidin 154, B. & La R. 484.

DILLENIACEAE

Saurauia nudiflora DC. var. sumatrana Baker; *sopsopan* (A.). — Silo Maradja, Bidin 14, B. & La R. 344.

Saurauia sp. — Bandar Pasir Mandoge, Galoengi 24, B. & La R. 22.

Tetracera scandens (L.) Merr.; *galingging* (A.). — Silo Maradja, Bidin 160, B. & La R. 490.

VIOLACEAE

Rinorea lanceolata (Wall.); *si balik hoemosing* (A.). — Silo Maradja, Bidin 134, B. & La R. 464.

FLACOURTIACEAE

Osmelia Bartlettii Merr. — Bandar Poelo, Galoengi 42, B. & La R. 37.

PASSIFLORACEAE

Adenia *cf.* acuminata King. — Bandar Poelo, Galoengi 44, B. & La R. 39.

Adenia sp.; *andor loting-loting* (A.). — Silo Maradja, Bidin 125, B. & La R. 455. Used as medicine.

Passiflora foetida L.; *gambo* (A.). — Silo Maradja, Bidin 43, B. & La R. 373. A food plant.

COMBRETACEAE

Combretum sundaicum Miq. — Boenoet, Galoengi 51, B. & La R. 45.

MYRTACEAE

Decaspermum paniculatum Kurz; *andomang* (A.). — Silo Maradja, Bidin 106, B. & La R. 436. A food plant.

Psidium guajava L.; *habo rasa* (A.). — Silo Maradja, Bidin 79, B. & La R. 409. The fruit is eaten.

MELASTOMACEAE

Dissochaeta gracilis Bl.; *si pitoe aroes* (A.). — Silo Maradja, Bidin 105, B. & La R. 435.

Melastoma polyanthum Bl.; *sandoekdoek* or *sandoelak* (A.); *sĕndoedoek* (K.). — Silo Maradja, Bidin 29, B. & La R. 359. Boenoet, Galoengi 4, B. & La R. 4. Used as a medicine. The native name, in various forms, is among the widespread ones of the Archipelago, but seems not to extend as far as the Philippines.

ONAGRACEAE

Jussieua suffruticosa L.; *soeke-soeke* (A.). — Silo Maradja, Bidin 130, B. & La R. 460.

Jussieua linifolia Vahl. — An admixture with the preceding, under the same number and vernacular name.

ARALIACEAE

Arthrophyllum pinnatum C. B. Clarke; *obang* (A.). — Silo Maradja, Bidin 30, B. & La R. 360.

Schefflera sp.; *si detoe* (A.). — Silo Maradja, Bidin 3, B. & La R. 333.

Schefflera sp.; *haroeppis* (A.). — Silo Maradja, Bidin 81, B. & La R. 411.

Trevesia Burkei Boerl.; *tada-tada* (K.). — Bandar Pasir Mandoge, Galoengi 35, B. & La R. 32.

MYRSINACEAE

Ardisia sp. — Bandar Poelo, Galoengi 46, B. & La R. 35.

Embelia dasythyrsa Miq.; *goring-goring* (A.). — Silo Maradja, Biden 152, B. & La R. 482.

EBENACEAE

Diospyros Wallichii King & Gamble; *boea sahoepang* (A.). — Silo Maradja, Bidin 15, B. & La R. 345.

OLEACEAE

Jasminum Sambac (L.) Ait.; *boenga tjoempaka* (A.). — Silo Maradja, Bidin 155, B. & La R. 485. In most Indonesian languages and dialects tjĕmpaka or some variant is the name of *Michelia Champaka* L. There is no Batak name in De Clercq for *Jasminum Sambac,* but the usual name is *melati* or some variant.

Ligustrum robustum (Roxb.) Bl.; *monis-monis* (A.). — Silo Maradja, Bidin 19, B. & La R. 349. Used as a medicine for boils.

LOGANIACEAE

Fagraea racemosa Jack; *rampisi* (A.). — Silo Maradja, Bidin 104, B. & La R. 434.

APOCYNACEAE

Rauwolfia perakensis King; *saloeng-saloeng* (A.). — Silo Maradja, Bidin 63, B. & La R. 393. Used for inflamed eyes and suppurating eyelids. (*Goenanja obat biring.*)

ASCLEPIADACEAE

Asclepias curassavica L.; *boenga sotororom* (A.). — Silo Maradja, Bidin 118, B. & La R. 448.

BORAGINACEAE

Heliotropium indicum L.; *roekoe-roekoe* (K.). — Boenoet, Galoengi 53, B. & La R. 47. The native name given is that applied in most dialects, even in Toba, according to De Clercq, to *Ocimum sanctum.* It is of course to be expected that names will in many cases be differently applied in different districts.

VERBENACEAE

Callicarpa arborea Roxb.; *hahomboe* (A.); *kimboe-kimboe* (K.). — Silo Maradja, Bidin 31, B. & La R. 361; Boenoet, Galoengi 47, B. & La R. 41.

Callicarpa longifolia Lam.; *si marsioesioe* (A.). — Silo Maradja, Bidin 89, B. & La R. 419. Used for medicine.

Clerodendron *cf.* fragrans Vent.; *sarang banoewa* (A.). — Silo Maradja, Bidin 12, B. & La R. 342. Used as medicine and in magical ceremonies.

Clerodendron paniculatum L.; *sipanggil* (A.). — Silo Maradja, Bidin 76, B. & La R. 406. Used in the rice ceremonies. As the name ("summoner") indicates, it is a means for calling the spirits together. The wide distribution of a similar custom is indicated by similar names for *Clerodendron calamitosum* in Malay (*pa panggil*) and Menangkabau (*si panggië-panggië*), and by the very significant Malay name *pawang boenga*, meaning the flower magician-priest. De Clercq says the plant is cultivated as an ornamental, serving here and there to drive away evil spirits. Similar names extend to the Philippines. Merrill [1] says "It is of interest to note that the allied Philippines species *Clerodendron intermedium* Cham. is currently known to the Tagalogs by a similar name, *casopanguil*." Guerrero [25] gives *kasopangil* as the name for *C. macrostegium* Schauer in Mindanao.

Clerodendron serratum (L.) Spr.; *si marbakkoedoe* (A.). — Silo Maradja, Bidin 115, B. & La R. 445. Its use is "to be placed with water" (*goenanja ditaroh sama ajer*).

Clerodendron villosum Bl.; *boerta-boerta* (A.). — Silo Maradja, Bidin 116, B. & La R. 446. De Clercq gives a totally different Batak name, *sihasoer*.

Lantana Camara L.; *mardoeridoeri andor* (A.). — Silo Maradja, Bidin 69, B. & La R. 399.

Premna pyramidata Wall. — Boenoet, Galoengi 52, B. & La R. 46.

[25] Guerrero, Leon Maria, "Medicinal Uses of Philippine Plants." In Brown, W. H., *Minor Products of Philippine Forests*, P. I. Dept. Agric. and Natural Resources, Bur. Forestry, Bull. 22, 3: 149–246. 1921.

VITEX PUBESCENS Vahl; *aloban* (A.) — Silo Maradja, Bidin 21, B. & La R. 351. Used for making household utensils and furniture. (*Goenanja perkakas roemah.*) The vernacular name is one of those extending through the Sunda Islands in various forms and applying to the same species everywhere.

LABIATAE

LEUCAS ZEYLANICA R. Br.; *lenggas* (K.). — Boenoet, Galoengi 57, B. & La R. 51.

OCIMUM BASILICUM L.; *leam, roedang na lopak, roedang na birong* (A.). — Silo Maradja, Bidin 82, 74, 6, B. & La R. 412, 404, 336. The plant is grown, in several forms, for ceremonial use as "*roedang.*" *Roedang na birong* is one of the things tendered the spirits in the offering known as "*boeloeng ni bagot.*"

OCIMUM SANCTUM L.; *roedang toba* (A.). — Silo Maradja, Bidin 73, B. & La R. 403. Equally as important in religious ceremony as the last. The Indic origin of the ceremonial usage of this and the preceding species is indicated by a name of Sanskrit or at least Hindu origin, *toelasi* or *soelasi*, which, in many variations, extends throughout Indonesia and northward to Luzon, where in Tagalog it is *solasi* or *sulasi.* Numerous scattered references to the ceremonial use of *Ocimum basilicum* and *O. sanctum* have been brought together and will be included in a subsequent article on the plants known as *roedang.*

SOLANACEAE

PHYSALIS ANGULATA L.; *poeltak-poeltak* (A.); *poeltok-poeltok* or *leoeh* (K.). — Silo Maradja, Bidin 120, B. & La R. 450; Boenoet, Galoengi 12 and 59, B. & La R. 12 and 59. Used as medicine.

SOLANUM MELONGENA L.; *tijoeng* (A.), *toroeng* (Mal., A., local dialect). — Generally planted for the fruits. The name is a variant of *tĕroeng* (Mal.) which is one of the Common Indonesian plant names. In some easily recognizable form it occurs in the majority of the languages and dialects from Nias to Celedes, and northward to the Philippines, where it is found in the form *talong* (Tagalog and Visayan).

Solanum nigrum L.; *poga* (A.). — Silo Maradja, Bidin 149, B. & La R. 479. The berries are eaten.

Solanum torvum Sw.; *rimbang* (A.), *boengkai rimbang* (K.). — Silo Maradja, Bidin 110, B. & La R. 440; Boenoet, Galoengi 5, B. & La R. 5. The fruits are eaten.

Solanum torvum Sw. (?); *ingir-ingir* (A.). — Silo Maradja, Bidin 107, B. & La R. 437. The fruit is cooked for food.

PEDALIACEAE

Sesamum orientale L.; *longa* (A.). — Silo Maradja, Bidin 38, B. & La R. 368. Used as food. See note in the following Karoland list.

GESNERIACEAE

Cyrtandra sp.; *si margaragara* (A.). — Silo Maradja, Bidin 136, B. & La R. 466.

ACANTHACEAE

Graptophyllum pictum (L.) Griff.; *salaon* (A.). — Silo Maradja, Bidin 11, B. & La R. 341. Used as medicine.

RUBIACEAE

Chasalia curviflora Thw.; *dajang* (K.). — Bandar Pasir Mandoge, Galoengi 28, B. & La R. 26.

Chasalia rostrata Miq.; *si harap* (A.). — Silo Maradja, Bidin 18, B. & La R. 348.

Hedyotis capitellata Wall.; *si martolor* (A.). — Silo Maradja, Bidin 99, B. & La R. 429. "The egg maker," in reference, of course, to the flower heads. The Asahan dialect word *tolor* is the equivalent of Malay *tĕlor*. The usual Toba word for egg, *pira*, occurs in the similar name for *Elephantopus scaber* and in the names for Alternanthera and Aerua.

Hedyotis scandens Roxb. (?); *andor sitomoe bona* (A.). — Silo Maradja, Bidin 129, B. & La R. 459.

Ixora nigricans R. Br.; *si marbosi* (A.). — Silo Maradja, Bidin 13, B. & La R. 343; Bandar Pasir Mandoge, Galoengi 26, B. & La R. 24.

Ixora salicifolia Bl.; *djaroem-djaroem pandjang* (A.), *djaong-djaong* (K.). — Silo Maradja, Bidin 157, B. & La R. 487; Bandar Pasir Mandoge, Galoengi 31, B. & La R. 29.

Ixora sp.; *djilok* (A.). — Silo Maradja, Bidin 145, B. & La R. 475.

Lasianthus sp. — Bandar Poelo, Galoengi 41, B. & La R. 36.

Mussaenda villosa Wall. — Bandar Poelo, Galoengi 43, B. & La R. 38.

Pavetta indica L.; *si parlis* (A.). — Silo Maradja, Bidin 97, B. & La R. 427.

Petunga longifolia Bl.; *potala* (A.). — Silo Maradja, Bidin 158, B. & La R. 488.

Tarenna mollis (Wall.) Valeton; *boeloeng ramboeng* (K.) — Boenoet, Galoengi 17, B. & La R. 17.

### CUCURBITACEAE

Citrullus vulgaris Schrad.; *mandehe* (A.). — Silo Maradja, Bidin 83, B. & La R. 413. The fruit is eaten.

Lagenaria leucantha (Lam.) Rusby; *djelok* (A.). — Silo Maradja, Bidin 53, B. & La R. 383. The fruit is used as a food.

Melothria sp.; *timoen tombak* (A.). — Silo Maradja, Bidin 137, B. & La R. 467. Used as food.

Trichosanthes (?) Momordica (?); *si martimoen* (A.). — Silo Maradja, Bidin 108, B. & La R. 438.

### COMPOSITAE

Ageratum conyzoides L.; *soeawa* (A.). — Silo Maradja, Bidin 66, B. & La R. 396. Used as medicine for fevers, especially ague and malaria.

Blumea balsamifera DC.; *boenga sapa* (A.), *galoenggoeng* (K.). — Silo Maradja, Bidin 151, B. & La R. 481; Boenoet, Galoengi 2, B. & La R. 2. Used as medicine. The Asahan name is the equivalent of Malay *tjapa* and Bugi, Makassar and Menangkabau *tjapo*. The Karo name is the same as the

Mandailing. A Toba name *langgoenggoeng sapa* illustrates a common method of word modification in Batak and other Indonesian languages, namely metathesis of the first two consonants of the word. By this process and a further modification of *g* to *ngg*, induced by the following *ngg*, *langgoenggoeng* is derived from *galoenggoeng*, and the formation of the word by reduplication and infixing of *al* is obscured. In Karo the name *boenga sapa* applies to *Impatiens spp.* (See note in Karoland list.)

Blumea pubigera (L.) Merr.; *boenga poetih* (A.). — Silo Maradja, Bidin 122, B. & La R. 452. The preceding species is sometimes known as *boenga poetih* in Mandailing.

Elephantopus scaber L.; *si marpirapira* (A.). — Silo Maradja, Bidin 2, B. & La R. 332. Used as medicine. (See note on *Hedyotis capitellata.*)

Emilia sonchifolia DC.; *aloem-aloem* (A.). — Silo Maradja, Bidin 35, B. & La R. 365. Used as a medicine for fever.

Spilanthes Acmella L.; *sihappir* (A.). — Silo Maradja, Bidin 54, B. & La R. 384. Used for medicine, and also, if *sihappir* is the same as Toba *sihampir*, which is almost certainly the case, believed to exercise an effect if merely named or represented. The flower conventionally represented on old-fashioned jewelry in Asahan, particularly on a certain type of breastpin, is said to be *sihampir*.

Vernonia cineria Less.; *si margalonggoeng* (A.). — Silo Maradja, Bidin 57, B. & La R. 387.

## List of Names in the Asahan Dialect

aloban, Vitex pubescens (*Verb.*)
aloem-aloem, Emilia sonchifolia (*Comp.*)
andomang, Decaspermum paniculatum (*Myrt.*)
andor loting-loting, Adenia sp. (*Passifl.*)
andor roegoen-roegoen, plant (indet.) with abnormality of the inflorescence caused by insects.
andor silo, Illigera dasyphylla (*Hernandiac.*)
andor siangir, Piper sp. (*Piperac.*)
andor sipalis, Grewia acuminata (*Till.*)
andor sirekrek, Tetrastigma lanceolarium (*Vit.*)
andor si tiga boeloeng, Kyllinga monocephala (*Cyp.*)
andor si tomoe bona, Hedyotis scandens (*Lab.*)

asosoran, Leea aequata (*Vit.*)
bagot, Arenga saccharifera (*Palm.*).
bajam, Amaranthus viridis (*Amaranth.*)
balingbing, Averrhoa Carambola (*Oxalid.*)
baringin, Ficus Benjamina (*Mor.*)
baroti, Piper sp. (*Piperac.*)
birah, Alocasia macrorrhiza (*Arac.*)
boea sahoepang, Diospyros Wallichii (*Eben.*)
boeloe tano, Panicum reptans (*Gram.*)
boeloe-boeloe, general term for bamboo
boenga poetih, Blumea pubera (*Comp.*)
boenga raja, Dianella odorata (*Lil.*)
boenga sapa, Blumea balsamifera (*Comp.*)
boenga sihampir, Spilanthes Acmella (*Comp.*)
boenga sotororom, Asclepias curassavica (*Asclep.*)
boenga tanaman, Ficus diversifolia var. (*Mor.*)
boenga tjoempaka, Jasminum Sambac (*Oleac.*)
boeloeng-boeloeng pagar, Wissadula periplocifolia (*Malv.*)
boerta-boerta, Clerodendron villosum (*Verb.*)
damar-damar, Smilax sp. (*Lil.*)
damar-damar aloes, Smilax sp. (*Lil.*)
dapdap, unidentified shrub.
dasdas, unidentified shrub.
dawa, Andropogon Sorghum (*Gram.*)
dingin-dingin, Bryophyllum calycinum (*Crass.*)
djagoel, djagoeng, Zea Mays (*Gram.*)
djaroem-djaroem, Pittosporum ferrugineum (*Pitt.*)
djaroem-djaroem aloes, Pittosporum ferrugineum (*Pitt.*)
djaroem-djaroem pandjang, Ixora salicifolia (*Rub.*)
djatoe, Anacardium sp. (*Anacard.*)
djelok, Lagenaria leucantha (*Cucurb.*)
djilok, Ixora sp. (*Rub.*)
djoeng-djoeng boehit, Neolitsea sp. (*Laur.*)
djoeragi, Brassica juncea var. (*Cruc.*)
djollama so begoe, Artocarpus champeden (*Mor.*)
djoring, Pithecolobium jiringa (*Leg.*)
doehoet (= roempoet Mal.) general name for small grasses.
doehoet besan, Centotheca latifolia (*Gram.*)
doehoet napa, Digitaria consanguinea (*Gram.*)
galinggang, Cassia alata (*Leg.*)
galingging, Tetracera scandens (*Dillen.*)
gambo, Passiflora foetida (*Passifl.*)
goeroe ni hambeng, Habenaria sp. (*Orch.*)
goeroe ni hambeng, Calanthe veratrifolia (*Orch.*)
goring-goring, Embelia dasythyrsa (*Myrsin.*)
habo rasa, Psidium guajava (*Myrt.*)
hadio, Vigna sinensis (*Leg.*)
hahomboe, Callicarpa arborea (*Verb.*)
halambir, Cocos nucifera (*Palm.*)

halawos, Alpinia (?) sp. (*Zing.*)
hanaë, Trema orientalis (*Ulm.*)
hapal-hapal, Bryophyllum sp. (*Crass.*)
hare-hare, Polypodium longissimum (*Polypod.*)
haroeppis, Schefflera sp. (*Aral.*)
hatoenggal, Hibiscus rosa-sinensis (*Malv.*)
hoenik, Curcuma zedoaria (*Zing.*)
hombil, Panicum sarmentosum (*Gram.*)
hori, Boehmeria nivea (*Urt.*)
hotang, Daemonorops oblongus (*Palm.*)
igar-igar, Hibiscus surrattensis (*Malv.*)
inggir-inggir, Solanum torvum (*Solan.*)
katjang risi, Phaseolus aureus (*Leg.*)
lappiang, Zingiber cf. Zerumbet (*Zing.*)
latong, indet. herb reputed to be very poisonous, — Bandar Pasir Mandoge, Asahan.
leam, Ocimum basilicum (*Lab.*)
limoh, orange, citrus fruit.
longa, Sesamum orientale (*Pedal.*)
longa-longa, Commersonia Bartramia (*Sterc.*)
lope, Psophocarpus tetragonolobus (*Leg.*)
losi, Piper arborescens (*Piperac.*)
losoe, Desmos (*Unona*) chinensis (*Anon.*)
mampoe, Macaranga tanarius (*Euph.*)
mandehe, Citrullus vulgaris (*Cucurb.*)
mardoeridoeri andor, Lantana Camara (*Verb.*)
marihoerihoer, Acalypha hispida (*Euph.*)
mənis-monis, Ligustrum robustum (*Oleac.*)
nakka, Artocarpus integra (*Mor.*)
obang, Arthrophyllum pinnatum (*Aral.*)
oendalangan, gen. & sp. indet. (*Orch.*)
padang roeroes, Eleusine indica (*Gram.*)
padang sila, Mariscus Sieberianus (*Cyp.*)
pahoe binggoe, Davallia solida (*Polypod.*)
pahoe lipan, Blechnum orientale (*Polypod.*)
pahoe riboe-riboe, Lygodium flexuosum (*Schiz.*)
pahoe riboe-riboe pandjang, Lygodium circinnatum (*Schiz.*)
pahoe roesi, Ceratopteris thalictroides (*Parkeriac.*)
palang, boenga palang, gen. & sp. indet. (*Zing.*)
palia djawa, Leucaena glauca (*Leg.*)
palia onggang, Mollugo pentaphylla (*Aiz.*)
palse-palse, Antidesma cuspidatum (*Euph.*)
pining, Areca Catechu L. (*Palm.*)
poeltak-poeltak, Physalis angulata (*Solan.*)
poerba djolma, Ampelocissus ochracea (*Vit.*)
poga, Solanum nigrum (*Solan.*)
potala, Petunga longifolia (*Rub.*)
raba-raba, Columella (Cayratia) japonica var. (*Vitac.*)
rampisi, Fagraea racemosa (*Logan.*)

ria-ria, Rhynchospora corymbosa (*Cyp.*)
ria-ria pandan, Cyperus elegans (*Cyp.*)
riang-riang, Antigonon leptopus (*Polygon.*)
rimbang, Solanum torvum (*Solan.*)
rinon ( = lalang Mal.), general term for large coarse grasses.
roedang na lopak, Ocimum basilicum (*Lab.*)
roedang soeroengan, Celosia cristata (*Amarant.*)
roedang gerger, roedang na gerger, Celosia argentea (*Amarant.*)
roedang na birong, Ocimum basilicum (*Lab.*)
roedang toba, Ocimum sanctum (*Lab.*)
roempoet aloes, Eragrostis pilosa (*Gram.*)
roempoet pandjang, Digitaria sanguinalis (*Gram.*)
saijo pais, Selaginella sp. (*Selagin.*)
saijo merah, Selaginella sp. (*Selagin.*)
salaon, Graptophyllum pictum, (*Acanth.*)
saloeng-saloeng, Rauwolfia perakensis (*Apoc.*)
samak-samak, Desmodium gangeticum (*Leg.*)
samodja, Bridelia tomentosa (*Euph.*)
sandoekdoek, Melastoma polyanthum (*Melast.*)
sandoelak, Melastoma polyanthum (*Melast.*)
sanggar, Themeda gigantea (*Gram.*)
sangge-sangge, Andropogon schoenanthus (*Gram.*)
sarang baganding, Lycopodium cernuum (*Lycop.*)
sarang banoewa, Clerodendron cf. fragrans (*Verb.*)
sarindan siala, Scindapsus or Raphiodophora (*Arac.*)
siala, boenga siala, Zingiber sp. (*Zing.*)
siala ngoengoe, gen. et sp. indet. (*Zing.*)
siala rodang, Globba sp. (*Zing.*)
siangir tombak, Piper caninum var. (*Piperac.*)
si aroem, Amaranthus gangeticus (*Amarant.*)
si bagoere, Sida rhombifolia (*Malv.*)
si balik hoemosing, Rinorea lanceolata (*Viol.*)
sibola, Uraria crinita (Leg.)
sidetoe, Scheffleria sp. (*Aral.*)
si hallong namboer, Panicum patens (*Gram.*)
sihampir, boenga sihampir, Spilanthes Acmella (*Comp.*)
sihappir, Spilanthes Acmella (*Comp.*)
siharsap, Chasalia rostrata (*Rub.*)
sihilap, Belamcanda (?) sp. (*Irid.*)
sihirpoet, Biophytum sensitivum (*Oxalid.*)
sikkoroe, Coix lachryma-Jobi (*Gram.*)
sikoeris, Leptaspis urceolata (*Gram.*)
si lambe boeloeng, Arenga saccharifera (*Palm.*)
si lindjoeang, Taetsia (*Cordyline*) fruticosa (*Lil.*)
silobar pinggan, Portulaca oleracea (*Portulac.*)
si marbagotbagot, Euphorbia hirta (*Euph.*)
si marbakkoedoe, Clerodendron serratum (*Verb.*)
si marbakkosbakkos, Micromelum pubescens (*Rut.*)
si marbosi, Ixora nigricans (*Rub.*)

si mardoeridoeri, Mimosa rubicunda (*Leg.*)
si margalagala, Phyllanthus Urinaria (*Euph.*)
si margalonggoeng, Vernonia cineria (*Comp.*)
si margaragara, Cyrtandra (*Gesn.*)
si marharehare, Loxogramme involuta (*Polypod.*)
si marihoerihoer ni asoe, Setaria italica (*Gram.*)
si marpalia, Dalbergia pinnata (*Leg.*)
si marpandanpandan, Cyperus elegans (*Cyp.*)
si marpirapira, Elephantopus scaber (*Comp.*)
si marsioesioe, Callicarpa longifolia (*Verb.*)
si martimoen, Trichosanthes (?) Momordica (?) (*Cucurb.*)
si martoelan, Macaranga javanica (*Euph.*)
si martolor, Hedyotis capitellata (*Rub.*)
sindoelpak, Homalanthus populneus (*Euph.*)
si nimnim, Claoxylon polot (*Euph.*)
sipanggil, Clerodendron paniculatum (*Verb.*)
siparlis, Pavetta indica (*Rub.*)
sipira, Alternanthera sessilis (*Amarant.*)
si pirapira, Aerua lanata (*Amarant.*)
si pitoe aroes, Dissochaeta gracilis (*Melast.*)
si rappas taloen, Oplismenus compositus (*Gram.*)
sisilon ni boet, Ziziphus calophylla (*Rham.*)
si soksok, Micromelum pubescens (*Rut.*)
sitanggis, Alpinia (?) (*Zing.*)
sitarak, Mallotus albus (*Euph.*)
sitopoe, Breynia racemosa (*Euph.*)
soeawa, Ageratum conyzoides (*Comp.*)
soeke-soeke, Jussieua suffruticosa and J. linifolia (*Onagr.*)
soekkit, Curculigo latifolia var. glabrescens (*Amaryll.*)
sopsopan, Saurauia nudiflora var. sumatrana (*Dill.*)
takkolan, Roucheria Griffithiana (*Lin.*)
tamba toba toea, Sida corylifolia (*Malv.*)
tijoeng, Solanum Melongena (*Solan.*)
timoen tombak, Melothria sp. (*Cucurb.*)
toboe, Saccharum officinarum (*Gram.*)
toeba sirah, Mallotus philippinensis (*Euph.*)
torop, Antiaris toxicaria (?) (*Morac.*)

## SPECIES COLLECTED IN KAROLAND

### FILICES

ANTROPHYUM CALLAEFOLIUM Bl. (?); *dilah antoe ara* (K.). — Soesoek, Galoengi 270, B. & La R. 264. The name means *tongue of the spirit ara.* A certain insect with a song like a cricket's is known as *ara-ara,* which gives some notion of the attributes of the *antoe ara.*

Cheilopleuria bicuspis (Bl.) Presl. — Soesoek, Liang-ndate, Galoengi 236, B. & La R. 231.

Cyclophorus sp.; *pildang* (K.). — Kaban Djahe, Galoengi 80, B. & La R. 80.

Drymoglossum heterophyllum (L.) C. Chr. — Singga Manik, Galoengi 172, B. & La. R. 167.

Lindsaea capillacea Christ. — Boekit, Goenoeng Toemanggoe, Galoengi 255 *bis*, B. & La R. 247.

Microlepia platyphylla (Don) J. Sm. (?); *pakoe* (K.). — Selandi, Galoengi 292, B. & La R. 286. *Pakoe* is practically a generic term for all ferns, and is modified by a specifying term in order to designate well-known kinds. *Pakoe* may be taken as one of the Common Indonesian plant names, since it is found in this form in Malay, Karo Batak, Simeloengoen, Atjehnese, Menangkabau, Sundanese, Balinese, Buginese, Makassar and Minahasa-Alfurese. In the last named dialect it passes to *pangoe*. With *pahoe* of Toba and Dairi Batak, *paoe* of Mandailing, and *fakoe* of Bimanese, the Southern Indonesian area is pretty thoroughly covered without including any debatable variants. For the Philippine languages we have Maguindanao *paco or pagco* ("helecho," *fide* Juanmarti); Visaya *paco* ("Planta, especie de helecho: sur tallos sirven para verdura y se perecen à los espárragos." — Sanchez); Tagalog *paco* "helechos," *fide* Domingo de los Santos; "una yerba comestible, un gusano que se cria en el pescado seco." — Noceda & San Lucar). Merrill gives *paco* as the Tagalog name for *Asplenium esculentum* Presl, stating that the young stems and leaves are much used as food by the natives. One is strongly tempted to try to trace this widespread word beyond the Indonesian area. In Samoan, one of the several meanings of *vao* is "a plant, a weed." In the reduplicated form, *vaovao*, it means small weeds. *Vaotuaniu* is "the name of a fern, *Pteris quadriaurita*." The Samoan *vao*, qualified, is sometimes, therefore, the name of a fern. Kern spells it *wao*, identifies it in the Maori *ko-wao*, or *wao-ko*, and relates it to Bisaya *baol* and Sangirese *waělě*, field, garden, cultivated land. Kern [26] himself, however, says that Polynesian

[26] Kern, H., De Fidji-taal. Verspr. Geschr. 5, v. pp. 91 and 133.

*w* may correspond to Indonesian *p*, and instances Samoan *wolu* (turtle), which is Fijian *vonu*, Malay *pañu* (*panjoe*), Javanese *pĕnjoe*, and Toba *ponoe*. The derivation of *vao* from *pakoe*, therefore, seems possible.

Odontosoria chinensis (L.) J. Sm. — Kaban Djahe, Galoengi 77, B. & La R. 77.

Polypodium mollicomum Bl. — Soesoek, Liang-ndate, Galoengi 235, B. & La R. 230.

Schizaea dichotoma (L.) Sm. — Singga Manik, Galoengi 165, B. & La R. 160.

Trichomanes gemmatum J. Sm. — Boekit, Goenoeng Toemanggoe, Galoengi 235 *bis*, B. & La R. 248.

### EQUISETACEAE

Equisetum debile Roxb.; *sĕndĕp-sĕndĕp* (K.). — Bintang Mariah, Galoengi 326, B. & La R. 319. The name is a reduplicated form of the word that denotes the close fitting of two things one within another, as a joint of Equisetum fits into the one below it.

### LYCOPODIACEAE

Lycopodium cernuum L.; *djarikdjak* (K.). — Bintang Mariah, Galoengi 329, B. & La R. 322. The name, derived from Karo *djikdjak*, Malay *djidjak*, designates a thing that hangs and has the free end dangling on the ground.

Lycopodium Phlegmaria L.; *taratinggi* (K.). — Soesoek, Goenoeng Soesoek, Galoengi 199, B. & La R. 194.

Lycopodium verticillatum L. — Boekit, Goenoeng Toemanggoe, Galoengi 255, B. & La R. 249.

### GRAMINEAE

Andropogon intermedius R. Br.; *padang sambo* (K.). — Soesoek, Galoengi 318 *bis*, B. & La R. 311 *bis*.

Andropogon Sorghum (L.) Brot.; *dawa* (K.). — Siberaja, Galoengi 337, B. & La R. 330. See note in Asahan list.

Andropogon serratus var. nitidus (Vahl) Hack.; *padang sambo* (K.). — Soesoek, Galoengi 318, B. & La R. 311.

Centotheca latifolia (Osb.) Trin. — Soesoek, Galoengi 273, B. & La R. 267.

Coix lachryma-Jobi L.; *tjingkerroe* (K.). — Selandi, Galoengi 293, B. & La R. 287. The form of the word in Toba is *singkoroe*. These two names are isolated, seemingly having no relationship to the other Indonesian names for Coix, which run through many languages. In Toba *singkoroe* is used in formulae of congratulation when it is not considered auspicious to say *boroe* (woman), just as a rhyming word *laklak* (bark) is under the same circumstances substituted for *anak* (child). Warneck [27] gives examples of the formulae.

Eleusine corocana (L.) Gaertn.; *djaba* (K.). — Si Beraja, Galoengi 336, B. & La R. 329. The name is merely a variant of *dawa*, the name for *Andropogon Sorghum*. (See note under the latter species in the Asahan list.) It is interesting to find two forms of the same word serving in Karo as names for different plants, a phenomenon to be explained, presumably, on the ground that one form is an old element of the language, whereas the other was borrowed later, after having undergone dialectical differentiation in a different dialect or language, in the latter designating a different plant and carrying its somewhat different meaning into Karo. The series of names *dawa, djawa, djaba*, etc., all apply to plants yielding small millet-like grains.

Eragrostis unioloides (Retz.) Nees. — Bintang Mariah, Galoengi 328, B. & La R. 321.

Ophiurus exaltatus (L.) O. Ktze.; *tĕrleng* (K.). — Bintang Mariah, Galoengi 327, B. & La R. 320.

Oplismenus compositus (L.) Beauv.; *koermil* (K.). — Serpang, Galoengi 187, B. & La R. 182.

Panicum indicum L.; *gamboet* (K.). — Boekit, Goenoeng Toemanggoe, Galoengi 261, B. & La R. 255.

Panicum palmaefolium Koenig; *kisik* (K.). — Serpang, Goenoeng Serpang, Galoengi 193, B. & La R. 188.

Panicum sarmentosum Roxb. — Sarinembah, Peddalong, Galoengi 247, B. & La R. 242.

Setaria flava (Nees) Kunth; *asoe-asoe* (K.). — Soesoek, Ga-

[27] Warneck, J., *Tobabataksch-Deutches Wörterbuch.* Batavia, 1906.

loengi 283, B. & La R. 277. The name, which is roughly translated dog-weed, is explained by comparison with the Asahan *si marihoerihoer ni asoe*, "the one that has a dog's tail."

CYPERACEAE

Scleria sumatrensis Retz.; *sajat-sajat* (K.). — Soesoek, Liang-ndate, Galoengi 230, B. & La R. 225.

COMMELINACEAE

Aneilema scaberrima Kunth. — Soesoek, Liang-ndate, Galoengi 215, B. & La R. 210.

Aneilema sp. — Serpang, Goenoeng Serpang, Galoengi 191, B. & La R. 186.

Commelina obliqua Ham. — Soeka Tendel, Galoengi 305, B. & La R. 297.

LILIACEAE

Peliosanthes sp. — Singga Manik, Galoengi 170, B. & La R. 165; Soesoek, Galoengi 272, B. & La R. 266.

Pleomele (Dracaena) elliptica N. E. Br. — Goenoeng Sinaboen, Galoengi 315, B. & La R. 308.

Smilax sp. — Singga Manik, Galoengi 177, B. & La R. 172.

Taetsia (Cordyline) fruticosa (L.) Merr.; *kalindjoehang* (K.). — Singga Manik, Galoengi 267, B. & La R. 261.

IRIDACEAE

Belamcanda chinensis Red.; *piso-piso* (K.). — Soesoek, Galoengi 280, B. & La R. 273.

ZINGIBERACEAE

Globba sp. — Soesoek, Liang-ndate, Galoengi 227, B. & La R. 222.

MARANTACEAE

Donax cannaeformis (Forst.) K. Sch.; *banban* (K.). — Lau Bakal, Galoengi 143, B. & La R. 140. In tracing the name

through Indonesia it is necessary to consider the names for Maranta, Clinogyne and Donax species together, as De Clercq has done. The variants of *banban* are then *banban* in Karo and Dairi, *bamban* in Menangkabau, Javanese and Sundanese, *bangban*, a second form in Sundanese, *bemban* in Malay, *bampeng* in Buginese, and *bomba* in Tomini Alfurese. Merrill notes (*in lit.*) that *banban* is the name for *Donax cannaeformis* in the Philippine Islands, and his *Dictionary of the Plant Names* gives both *banban* and *bamban* as Tagalog for Maranta. He gives *bangbang* as the name for *Clinogyne grandis* B. & H. (Morong). The Visayan dictionary (Sanchez) gives *banban* as "planta que suple por el bejuco limpio." The name *banban* is therefore Common Indonesian, and is one of the plant names of which it is worth while to attempt to trace the origin and the migrations beyond Indonesia.

Phrynium parviflorum Roxb.; *banban belok* (K.). — Singga Manik, Galoengi 162, B. & La R. 157.

BURMANNIACEAE

Burmannia longifolia Becc. — Soeka Tendel, Galoengi 311, B. & La R. 304.

ORCHIDACEAE

Agrostophyllum sp. — Kaban Djahe, Galoengi 86, B. & La R. 86.

Aphyllorchis sp. — Serpang, Goenoeng Serpang, Galoengi 121, B. & La R. 119.

Apostasia Wallichii R. Br. — Goenoeng Sinaboen, Galoengi 314, B. & La R. 307.

Bromheadia sp.; *kapias rih* (K.). — Kaban Djahe, Galoengi 102, B. & La R. 101; Sarinembah, Peddalong, Galoengi 250, B. & La R. 245.

Calanthe veratrifolia R. Br. — Soeka Tendel, Makam, Galoengi 307, B. & La R. 299.

Coelogyne sp.; *boenga rinte* (K.). — Pĕrbessi, Si Tangger, Galoengi 335, B. & La R. 328.

Dendrobium sp. (?); *pĕldang radja* (K.). — Kaban Djahe, Galoengi 105, B. & La R. 104.

Dendrobium sp.; *tongkil begoe* (K.). — Kaban Djahe, Galoengi 107, B. & La R. 106.

Eria sp. — Soesoek, Liang-ndate, Galoengi 233, B. & La R. 228.

Liparis longipes Lindl. — Singga Manik, Galoengi 158, B. & La R. 153.

Malaxis sp. — Boekit, Goenoeng Toemanggoe, Galoengi 260, B. & La R. 254.

Nieuwiedia veratifolia Bl.; *singkoet* (K.). — Kaban Djahe, Galoengi 76, B. & La R. 76.

Orchidac. gen. et sp. indet.; *tongkil-tongkil* (K.). — Kaban Djahe, Galoengi 78, B. & La R. 78.

Orchidac. gen. et sp. indet.; *katji rah-rah.* — Lingga, Galoengi 116, B. & La R. 114.

Spathiglottis plicata Bl.; *rĕkat* (K.). — Kaban Djahe, Galoengi 100, B. & La R. 99.

CHLORANTHACEAE

Chloranthus brachystachys Bl. — Serpang, Goenoeng Serpang, Galoengi 128, B. & La R. 126.

Chloranthus officinalis Bl. — Kaban Djahe, Galoengi 98, B. & La R. 97.

MORACEAE

Cudrania javanensis Bl.; *siro* (K.). — Kaban Djahe, Galoengi 97, B. & La R. 96.

Ficus Motleya Miq. — Soesoek, Liang-ndate, Galoengi 234, B. & La R. 229.

Ficus parietalis Bl.; *kĕrakap* (K.). — Sarinembah, Peddalong, Galoengi 142, B. & La R. 139.

Ficus subulata Bl.; *kĕtĕp-kĕtĕp mentji* (K.). — Kaban Djahe, Galoengi 91, B. & La R. 91; Boekit, Goenoeng Toemanggoe, Galoengi 263, B. & La R. 257.

Morus alba L.; *amba toeah* (K.). — Selandi, Galoengi 294, B. & La R. 288.

URTICACEAE

Boehmeria nivea Gaudich. — Bintang Mariah, Galoengi 136, B. & La R. 133.

Dubregeasia longifolia (Burm.) Wedd.; *tjeppira* (K.). — Kaban Djahe, Galoengi 81, B. & La R. 81.

Elatostema sp. — Soesoek, Galoengi 271, B. & La R. 265.

Elatostematoides Thibaudianum C. B. Rob. — Kaban Djahe, Galoengi 74, B. & La R. 74.

Oreocnide nivea Merr.; *nderasi* (K.). — Soesoek, Goenoeng Sinaboen, Galoengi 218, B. & La R. 213. This species is erroneously attributed to Asahan in the original description in *Phil. Journ. Sci.*, 14: 239–250. 1919.

Oreocnide rubescens Miq. — Singga Manik, Galoengi 157, B. & La R. 152.

PROTEACEAE

Helicia n. sp. (near *H. Kingiana.*). — Serpang, Goenoeng Serpang, Galoengi 125, B. & La R. 123.

OLACACEAE

Erythropalum scandens Bl. — Singga Manik, Galoengi 175, B. & La R. 170.

POLYGONACEAE

Polygonum barbatum L.; *toeba pajan* (K.). — Bintang Mariah, Galoengi 331, B. & La R. 324.

Polygonum chinense L. — Selandi, Galoengi 298, B. & La R. 292.

AMARANTHACEAE

Aerua lanata (L.) Juss. — Bintang Mariah, Galoengi 135, B. & La R. 132.

Amaranthus paniculatus L.; *aroem boenia* (K.). — Soesoek, Galoengi 277, B. & La R. 271.

Amaranthus spinosus L.; *aroemĕn* (K.). — Pĕrbessi, Si Tangger, Galoengi 324, B. & La R. 317.

Celosia argentea L.; *aroem alas* (K.). — Soesoek, Liang-ndate, Galoengi 244, B. & La R. 239.

Cyathula prostrata (L.) Bl.; *si bĕrani* (K.). — Soesoek, Galoengi 274, B. & La R. 268.

MAGNOLIACEAE

Talauma mutabilis Bl. — Serpang, Goenoeng Serpang, Galoengi 127, B. & La R. 125.

ANONACEAE

Desmos (Unona) Wrayi (Hemsl.) Safford. — Singga Manik, Galoengi 176, B. & La R. 171.

Polyalthia sp. — Soesoek, Goenoeng Soesoek, Galoengi 201, B. & La R. 196.

LAURACEAE

Cryptocarya sp. — Soesoek, Goenoeng Sinaboen, Galoengi 222, B. & La R. 217.

Litsea perakensis Gamble. — Lingga, Galoengi 119, B. & La R. 117.

Litsea resinosa Bl. (*val. aff.*). — Singga Manik, Galoengi 156, B. & La R. 151.

Litsea sp. — Kaban Djahe, Galoengi 92, B. & La R. 92.

Litsea sp. — Lingga, Galoengi 117, B. & La R. 115.

NEPENTHACEAE

Nepenthes *cf.* mirabilis (Lour.) Merr.; *takor-takor* (K.) — Pĕrbessi, Si Tangger, Galoengi 323, B. & La R. 316.

CRASSULACEAE

Bryophyllum pinnatum Kurz; *kapal-kapal* (K.). — Soesoek, Liang-ndate, Galoengi 209, B. & La R. 204.

SAXIFRAGACEAE

Dichroa febrifuga Lour. — Soesoek, Goenoeng Sinaboen, Galoengi 220, B. & La R. 215.

ROSACEAE

RUBUS ALCEAEFOLIUS Poir.; *koepi-koepi* (K.). — Kaban Djahe, Galoengi 110, B. & La R. 109.

RUBUS MOLUCCANUS L.; *koepikoepian* (K.). — Soesoek, Galoengi 224, B. & La R. 219.

CONNARACEAE

CONNARUS SP. — Sarinembah, Peddalong, Galoengi 137, B. & La R. 134.

LEGUMINOSAE

ALYSCICARPUS VAGINALIS DC.; *nakan bĕnang* (K.). — Singga Manik, Galoengi 180, B. & La R. 175.

CAJANUS CAJAN (L.) Millsp.; *ritik rias* (K.). — Soesoek, Liang-ndate, Galoengi 243, B. & La R. 238.

CASSIA OCCIDENTALIS L.; *galinggang* (K.). — Sarinembah, Lau Bakal, Galoengi 246, B. & La R. 241.

CLITORIA TERNATA L.; *binbinĕn* (K.). — Singga Manik, Galoengi 173, B. & La R. 168.

CROTALARIA FERRUGINEA Grah. — Selandi, Galoengi 291, B. & La R. 285.

DESMODIUM GYRANS DC.; *tinggĕrĕn* (K.). — Serpang, Goenoeng Serpang, Galoengi 182, B. & La R. 177.

DESMODIUM GYROIDES DC. — Serpang, Goenoeng Serpang, Galoengi 194, B. & La R. 189.

DESMODIUM LASIOCARPUM DC.; *gambor-gambor* (K.). — Soesoek, Galoengi 319, B. & La R. 312.

DESMODIUM SCALPE DC. — Soesoek, Galoengi 275, B. & La R. 269.

DESMODIUM VIRGATUM Zoll.; *gamber-gamber* (K.). — Bintang Mariah, Galoengi 131, B. & La R. 128.

DESMODIUM ZONATUM Miq. — Sarinembah, Galoengi 148, B. & La R. 145.

FLEMINGIA MACROPHYLLA Willd. — Soeka Tendel, Galoengi 308, B. & La R. 301.

FLEMINGIA STROBILIFERA R. Br.; *goeak* (K.). — Soesoek, Galoengi 202, B. & La R. 197.

Indigofera tinctoria L.; *tĕllep* (K.). — Sarinembah, Galoengi 146, B. & La R. 143.

Leguminosarum gen. et sp. indet.; *ndoepar* (K.). — Serpang, Goenoeng Serpang, Galoengi 195, B. & La R. 190.

Pithecolobium jiringa (Jack) Prain; *djĕrring* (K.). —Singga Manik, Galoengi 151, B. & La R. 148.

RUTACEAE

Glycosmis cochinchinensis Pierre. — Goenoeng Sinaboen, Galoengi 316, B. & La R. 309; Lingga, Galoengi 112, B. & La R. 110.

Evodia sp.; *si tĕloe boeloeng* (K.). — Singga Manik, Galoengi 266, B. & La R. 260.

SIMARUBACEAE

Picrasma javanica Bl. — Serpang, Galoengi 184, B. & La R. 179.

MELIACEAE

Aglaia eximia T. & B.; *baur* (K.). — Soesoek, Liang-ndate, Galoengi 210, B. & La R. 205.

Cipadessa baccifera (Roth.) Miq.; *koendĕlen pamal* (K.). — Bintang Mariah, Galoengi 333, B. & La R. 326.

EUPHORBIACEAE

Acalypha hispida Burm. f.; *ikor-ikor* (K.). — Soesoek, Liang-ndate, Galoengi 238, B. & La R. 233.

Antidesma cuspidatum Muell. — Lingga, Galoengi 118, B. & La R. 116.

Claoxylum longifolium (Bl.) Miq. — Singga Manik, Galoengi 268, B. & La R. 262.

Fluggea virosa Baill. — Singga Manik, Galoengi 179, B. & La R. 174.

Gelonium glomerulatum Hassk. — Singga Manik, Galoengi 171, B. & La R. 116.

Glochidium sp. — Selandi, Galoengi 295, B. & La R. 289.

Macaranga javanica Bl. — Selandi, Galoengi 301, B. & La R. 294.

Macaranga triloba Muell.; *tjapĕt* (K.). — Kaban Djahe, Galoengi 93, B. & La R. 93.

Macaranga sp. — Singga Manik, Galoengi 169, B. & La R. 164.

Mallotus dispar Muell. — Bintang Mariah, Galoengi 133, B. & La R. 130.

Melanolepis multiglandulosa (Reinw.) R. & Z. — Sarinembah, Peddalong, Galoengi 251, B. & La R. 246.

Sauropus *cf.* forcipatus Hook. f.; *gĕning-gĕning* (K.). — Singga Manik, Galoengi 163, B. & La R. 158.

Sebastiana chamaelea Muell. — Serpang, Goenoeng Serpang, Galoengi 181, B. & La R. 176.

Sumbaviopsis albicans (Bl.) J. J. Sm.; *sĕmpalingen* (K.). — Bintang Mariah, Galoengi 134, B. & La R. 131.

### CELASTRACEAE

Perrottetia alpestris (Bl.) Loesen. — Soesoek, Goenoeng Sinaboen, Galoengi 223, B. & La R. 218.

### ICACINACEAE

Gomphandra sp. — Soesoek, Goenoeng Soesoek, Galoengi 200, B. & La R. 195.

### SAPINDACEAE

Allophylus sumatranus Bl. — Soesoek, Liang-ndate, Galoengi 212, B. & La R. 207.

Allophylus villosus Bl. — Kaban Djahe, Galoengi 99, B. & La R. 98.

Allophylus ternatus Radlk. — Kaban Djahe, Galoengi 109, B. & La R. 108.

### SABIACEAE

Meliosma simplicifolia Roxb. — Serpang, Goenoeng Serpang, Galoengi 190, B. & La R. 185.

BALSAMINACEAE

Impatiens sp.; *boenga sapa* or *boenga sapa-sapa* (K.). — Kaban Djahe, Galoengi 108, B. & La R. 107; Boekit, Goenoeng Toemanggoe, Galoengi 264, B. & La R. 258. Karo *sapa* is related to *katjar* (Karo and Gajo), *pantjar* (Sasak), *pasar* (Dyak, S. E. Borneo), *patjar* (Balinese, Madurese), *patjara* (Makassar), *patji* (Buginese), *patjah* (Balinese), and *kapantja* (Bimanese), names applied sometimes to Impatiens and sometimes to *Lawsonia inermis* L., because both are used for staining the finger nails red. The Balinese *patjah* is the nearest to *sapa*. Such a form could give rise to *sapa* by metathesis and mutation of *tj* to *s*, a very common change indeed, but one that would indicate that *sapa* is a borrowed word in Karo, perhaps from Toba, since Karo has the sound *tj*, which is always represented by *s* in Toba. The persistence of *katjar* in Karo as another name for the same plant would also be good proof that *sapa* is borrowed from Toba. In Asahan *sapa* applies to *Blumea balsamifera* (*langgoenggoeng sapa* in Toba). A similar medicinal or ceremonial use doubtless accounts for such widely different plants as Impatiens and Blumea having the same name. Recognizing the etymological identity of Karo *sapa* with Asahan *sapa*, we are enabled to add certain names of Blumea to the *katjar* series, as follows: *tjapa* (Mal.), *tjapo* (Buginese and Menangkabau). The Malay *tjapa* falls into place as the hypothetical intermediate between Toba *sapa* and Balinese *patjah*.

RHAMNACEAE

Colubrina asiatica Rich. — Kaban Djahe, Galoengi 72, B. & La R. 72.

Rhamnus javanica Bl. — Soesoek, Liang-ndate, Galoengi 240, B. & La R. 235.

VITACEAE

Tetrastigma sp.; *kĕrpe baloe* or *waren kĕrpe baloe* (K.). — Lingga, Galoengi 115, B. & La R. 113. "The widow's pot ring." Kĕrpe is a woven or twisted ring to set a round-bottomed pot upon.

TILIACEAE

Grewia paniculata Roxb.; *ndiwah* (K.). — Singga Manik, Galoengi 161, B. & La R. 156.

Triumfetta tomentosa Roth; *pidger keling* (K.). — Selandi, Galoengi 288, B. & La R. 282.

MALVACEAE

Abelmoschus moschatus Moench. — Soesoek, Liang-ndate, Galoengi 228, B. & La R. 223.

Hibiscus macrophylla Roxb.; *anoekanoek* (K.). — Soesoek, Liang-ndate, Galoengi 214, B. & La R. 209.

Malvac. gen & sp. indet.; *koedin-koedin* (K.). — Singga Manik, Galoengi 164, B. & La R. 159.

Sida corylifolia Wall.; *hoeboeng-hoeboeng* (K.). — Singga Manik, Galoengi 152, B. & La R. 149.

Sida retusa L.; *berasan* or *beras-beras* (K.). — Serpang, Galoengi 183, B. & La R. 178.

STERCULIACEAE

Commersonia bartramia (L.) Merr. — Serpang, Goenoeng Serpang, Galoengi 196, B. & La R. 191.

Firmiana colorata (Roxb.) R. Br.; *tjipa-tjipa* (K.). — Soesoek, Liang-ndate, Galoengi 211, B. & La R. 206.

Leptonychia heteroclita (Roxb.) Kurz. — Soesoek, Liang-ndate, Galoengi 213, B. & La R. 208.

Melochia umbellata (Houtt.) Stapf; *mběttak* (K.). — Sarinembah, Peddalong, Galoengi 139, B. & La R. 136.

Sterculia *cf.* andamanica Prain. — Kaban Djahe, Galoengi 103, B. & La R. 102.

Sterculia sp. — Lingga, Galoengi 114, B. & La R. 112.

DILLENIACEAE

Saurauia *cf.* hirta Bl. — Lingga, Galoengi 120, B. & La R. 118.

Saurauia tristyla DC. var. sumatrana Baker. — Kaban Djahe, Galoengi 82, B. & La R. 82.

Saurauia sp. — Selandi, Galoengi 302, B. & La R. 295; Soesoek, Liang-ndate, Galoengi 231, B. & La R. 226.

THEACEAE

Eurya acuminata Wall.; *kělempen* (K.). — Bintang Mariah, Galoengi 132, B. & La R. 129.

GUTTIFERAE

Hypericum japonicum Thunb. — Selandi, Galoengi 296, B. & La R. 290.

VIOLACEAE

Viola Patrinii Ging.; *tjaloeng-tjaloeng* (K.) — Soeka Tendel, Galoengi 310, B. & La R. 303.

BEGONIACEAE

Begonia sp.; *riang-riang* (K.). — Kaban Djahe, Galoengi 101, B. & La R. 100.

Begonia sp. — Kaban Djahe, Galoengi 106, B. & La R. 105.

Begonia sp. — Sarinembah, Lau Bakal, Galoengi 205, B. & La R. 200.

ELEAGNACEAE

Eleagnus conferta Roxb. — Singga Manik, Galoengi 178, B. & La R. 173.

Eleagnus triflora Roxb. — Soesoek, Galoengi 284, B. & La R. 278.

MYRTACEAE

Eugenia densiflora DC. — Sarinembah, Lau Bakal, Galoengi 203, B. & La R. 198.

MELASTOMACEAE

Memecylon La Ruei Merr. — Soesoek, Liang-ndate, Galoe-

ngi 241, B. & La R. 236. (Type locality not in Asahan, as erroneously recorded in *Phil. Journ. Sci.*, 14: 239–250. 1919.)

SONERILA TENUIFOLIA Bl. — Boekit, Goenoeng Toemanggoe, Galoengi 258, B. & La R. 252.

ONAGRACEAE

JUSSIEUA SUFFRUTICOSA L. — Soesoek, Galoengi 282, B. & La R. 276.

ARALIACEAE

SCHEFFLERA SP.; *ling kĕrsap* (K.). — Sarinembah, Peddalong, Galoengi 140, B. & La R. 137.

UMBELLIFERAE

HYDROCOTYLE JAVANICA Thunb. — Soesoek, Liang-ndate, Galoengi 226, B. & La R. 221.

MYRSINACEAE

ARDISIA LANCEOLATA Roxb. — Soesoek, Liang-ndate, Galoengi 225, B. & La R. 220.

ARDISIA SANGUINOLENTA Bl.; *koadji* (K.). — Soesoek, Liang-ndate, Galoengi 216, B. & La R. 211.

ARDISIA SP.; *tjep-tjep perik* (K.). — Kaban Djahe, Galoengi 83, B. & La R. 83.

ARDISIA SP. — Sarinembah, Galoengi 145, B. & La R. 142.

ARDISIA SP. — Singga Manik, Galoengi 166, B. & La R. 161.

MAESA INDICA Wall. — Singga Manik, Galoengi 265, B. & La R. 259.

SYMPLOCACEAE

SYMPLOCOS RUBIGINOSA Wall. — Sarinembah, Lau Bakal, Galoengi 207, B. & La R. 202.

OLEACEAE

JASMINUM SP. — Singga Manik, Galoengi 174, B. & La R. 169.

Ligustrum robustum (Roxb.) Bl. — Kaban Djahe 73, B. & La R. 73.

LOGANIACEAE

Buddleia asiatica Lour. — Kaban Djahe, Galoengi 85, B. & La R. 85.

GENTIANACEAE

Exacum chironioides Griseb. — Singga Manik, Galoengi 159, B. & La R. 154.

APOCYNACEAE

Perameria barbata (Bl.) K. Sch. — Singga Manik, Galoengi 160, B. & La R. 155.

Plumiera acutifolia Poir.; *boenga simpa* (K.). — Soesoek, Galoengi 285, B. & La R. 279.

Rauwolfia perakensis King. — Kaban Djahe, Galoengi 94, B. & La R. 94; Serpang, Galoengi 198, B. & La R. 193.

ASCLEPIDACEAE

Asclepias curassavica L. — Sarinembah, Peddalong, Galoengi 248, B. & La R. 243.

Dischidia sp. — Serpang, Goenoeng Serpang, Galoengi 130, B. & La R. 127.

VERBENACEAE

Callicarpa longifolia Lam. — Soeka Tendel, Makam, Galoengi 307 *bis*, B. & La R. 300.

Callicarpa rubella Lindl. var. — Bintang Mariah, Galoengi 330, B. & La R. 323.

Clerodendron serratum (L.) Spr.; *rimba tasik* (K.). — Selandi, Galoengi 303, B. & La R. 296.

Clerodendron villosum Bl. — Kaban Djahe, Galoengi 90, B. & La R. 90.

Clerodendron sp. — Lingga, Galoengi 113, B. & La R. 111.

Clerodendron sp. — Bintang Mariah, Galoengi 334, B. & La R. 327.

STACHYTARPHETA JAMAICENSIS Vahl. — Serpang, Galoengi 188, B. & La R. 183.

VITEX TRIFOLIA L.; *salagoendi* (K.). — Sarinembah, Peddalong, Galoengi 249, B. & La R. 244. This species and its allies have many uses and consequently a Common Indonesian name. Not only is the wood a useful one for house timbers, but also the aromatic foliage, which gives an odorous smudge when burned, is used in various ceremonies which have as their object the repelling of evil spirits. It is used to protect the sick, women in child-birth, etc. The name with a qualifying adjective or compounded may be transferred to other odorous plants similarly used. Probably the ceremonial rather than the practical use, together with the wide distribution of the plant, has secured for the name of this species a place in most of the Indonesian languages. De Clercq quotes, aside from various unrelated names (for there is more than one widely distributed series) the following: *sija lagoendi* (Batak), *silagoendi* (Menangkabau), *lagoendi* (Malay), *legoendi* (Malay and Javanese), *lagondi* (Sundanese), *lagonde* (Minahassa), *lenggoendi* (Malay), *lengoendi* (Sasak), *langghoendhi* (Madurese), *liligoendi* and *liligondi* (Balinese). Merrill gives for the Philippines *lagundi* (Tagalog), *lagundin dagat* (dialect not given), and *lagunding gapang* (Tagalog for *Vitex obovata* Thunb.). The form *lagundi* is doubtless the original Indonesian word, or very close to it.

LABIATAE

COLEUS ATROPURPUREUS Benth.; *aroem gara* (K.). — Kaban Djahe, Galoengi 79, B. & La R. 79.

GOMPHOSTEMMA OBLONGUM Wall. — Soesoek, Liang-ndate, Galoengi 229, B. & La R. 224.

HYPTIS SUAVEOLENS Jacq.; *děreng-děreng* (K.). — Soesoek, Galoengi 276, B. & La R. 270.

SOLANACEAE

SOLANUM BIFLORUM Lour.; *kapal-kapal kěrangen* (K.). — Singga Manik, Galoengi 167 and 168, B. & La R. 162 and 163.

Solanum indicum L.; *boengkai* (K.) — Singga Manik, Galoengi 153, B. & La R. 150.

PEDALIACEAE

Sesamum orientale L.; *lĕngnga* (K.). — Sarinembah, Galoengi 147, B. & La R. 144. On account of its utility and broad distribution in cultivation it is quite in accordance with expectation to find a Common Indonesian name. As variants of the Karo form of the name we find *lengong* (Atjeh), *longa* (Toba and Nias), *lango* (Menangkabau), *lengoe* or *lingoe* (Lampong), *lenga* (Malay, Balinese and Buginese), *lengo* (Dayak of S.E. Borneo), *lena* (Rotinese), and *ringa* (Bimanese). For the Philippine area Merrill records *langa* (Cagayan), *langis* (Pampangan), *langnga, lengnga, linga,* and *languis* (Tagalog), and *longa* (Visayan). The Karo form *lengnga* is probably close to the primitive Indonesian form, if we may accept Brandstetter's conclusion that this language is remarkably archaic.

GESNERIACEAE

Cyrtandra basiflora C. B. Clarke. — Sarinembah, Lau Bakal, Galoengi 208, B. & La R. 203.

Cyrtandra sp.; *si bantjir* (K.). — Soesoek, Galoengi 278 and 279, B. & La R. 272.

Cyrtandra sp. — Sarinembah, Lau Bakal, Galoengi 206, B. & La R. 201.

Didymocarpus sp. — Boekit, Goenoeng Toemanggoe, Galoengi 259, B. & La R. 253.

Gesneriac. gen. & sp. indet. — Boekit, Goenoeng Toemanggoe, Galoengi 262, B. & La R. 256; Kaban Djahe, Galoengi 87, B. & La R. 87.

Trichosporum sp.; *sitamtam* or *tamtam* (K.). — Soesoek, Galoengi 269, B. & La R. 263.

ACANTHACEAE

Graptophyllum pictum (L.) Griff.; *sĕlantam* (K.). — Selandi, Galoengi 286, B. & La R. 280.

JUSTICIA GANDARUSSA L. f.; *bĕsi-bĕsi* (K.). — Soesoek, Liang-ndate, Galoengi 242, B. & La R. 237.

JUSTICIA sp. (?). — Soesoek, Goenoeng Sinaboen, Galoengi 221, B. & La R. 216.

PSEUDANTHEREMUM sp.; *sitĕpoe* (K.). — Sarinembah, Lau Bakal, Galoengi 245, B. & La R. 240.

RUELLIA *cf.* FLAGELLIFORMIS Roxb. — Serpang, Goenoeng Serpang, Galoengi 123, B. & La R. 121.

STROBILANTHES sp.; *si tot-tot* (K.). — Kaban Djahe, Galoengi 71, B. & La R. 71.

RUBIACEAE

ARGOSTEMMA MONTANUM Bl. — Boekit, Goenoeng Toemanggoe, Galoengi 256, B. & La R. 250.

IXORA NIGRICANS R. Br. — Goenoeng Sinaboen, Galoengi 317, B. & La R. 310.

IXORA SALICIFOLIA Bl.; *djaoengen* or *djaoeng-djaoeng* (K.). — Serpang, Goenoeng Serpang, Galoengi 122, B. & La R. 120.

IXORA sp. — Soesoek, Galoengi 321, B. & La R. 314.

IXORA sp. — Goenoeng Sinaboen, Galoengi 313, B. & La R. 306.

IXORA sp. — Sarinembah Peddalong, Galoengi 141, B. & La R. 138.

LASIANTHUS OBLONGUS K. & G. — Soesoek, Liang-ndate, Galoengi 217, B. & La R. 212.

LASIANTHUS RHINOCEROTIS Bl. — Bintang Mariah, Galoengi 332, B. & La R. 325.

MYCETIA LATERIFLORA Kth. — Kaban Djahe, Galoengi 84, B. & La R. 84.

OPHIORRHIZA sp. — Sarinembah, Lau Bakal, Galoengi 204, B. & La R. 199.

PAEDERA FOETIDA L. — Selandi, Galoengi 297, B. & La R. 291; Kaban Djahe, Galoengi 88, B. & La R. 88.

PAVETTA sp. — Sarinembah Peddalong, Galoengi 138, B. & La R. 135.

PSYCHOTRIA LAXIFLORA Bl. — Serpang, Goenoeng Serpang, Galoengi 185, B. & La R. 180.

Psychotria viridiflora Bl. — Soesoek, Galoengi 320, B. & La R. 313.

Psychotria sp. — Serpang, Goenoeng Serpang, Galoengi 126, B. & La R. 124.

Tarenna mollis (Wall.) Robinson; *djaroem-djaroem* (K.). — Kaban Djahe, Galoengi 89, B. & La R. 89.

Tarenna sp.; *si oeban-oeban* (K.). — Kaban Djahe, Galoengi 75, B. & La R. 75.

Urophyllum arboreum (Reinw.) Korth. — Galoengi 312, B. & La R. 305.

CAPRIFOLIACEAE

Sambucus javanica Bl.; *sĕlando* (K.). — Kaban Djahe, Galoengi 96, B. & La R. 95.

CUCURBITACEAE

Gynostemma laxum (Wall.) Cogn.; *warĕn* (K.). — Soeka Tendel, Galoengi 309, B. & La R. 302.

Melothria sp. — Serpang, Galoengi 189, B. & La R. 184.

COMPOSITAE

Adenostemma lavenia (L.) O. Ktze.; *pĕssel* (K.). — Sarinembah, Galoengi 149, B. & La R, 146.

Ageratum conyzoides L.; *taloe dagang* (K.). — Selandi, Galoengi 290, B. & La R. 284.

Artemisia vulgaris L.; *binara* (K.). — Selandi, Galoengi 287, B. & La R. 281.

Bidens pilosa L.; *sari pĕgĕk* (K.). — Selandi, Galoengi 299, B. & La R. 293.

Blumea aromatica DC. — Soesoek, Galoengi 281, B. & La R. 275, Soeka Tendel, Makam, Galoengi 306, B. & La R. 298.

Cosmos caudatus HBK.; *gĕrat-gĕrat* (K.). — Serpang, Galoengi 197, B. & La R. 192.

Erigeron linifolius Willd.; *ser-ser* (K.). — Selandi, Galoengi 289, B. & La R. 283.

Gynura sarmentosa DC. (?). — Kaban Djahe, Galoengi 104, B. & La R. 103.

Mikania scandens Willd.; *si roengkas* (K.). — Soesoek, Liang-ndate, Galoengi 237, B. & La R. 232.

Synedrella nodiflora Gaertn. — Pĕrbessi, Galoengi 325, B. & La R. 318.

Tithonia diversifolia A. Gray. — Soesoek, Galoengi 322, B. & La R. 315.

Vernonia arborea Ham.; *bernaik* (K.). — Soesoek, Liang-ndate, Galoengi 239, B. & La R. 234.

Vernonia patula (Ait.) Merr. — Sarinembah, Galoengi 150, B. & La R. 147.

## List of Names in the Karo Language

If the Latin name is marked with an asterisk, the species will be found in the Asahan list. If not so marked, it will be found in the Karoland list.

amba toeah, Morus alba (*Mor.*)
anoek-anoek, Hibiscus macrophylla (*Malv.*)
aroem alas, Celosia argentea (*Amarant.*)
aroem boenia, Amaranthus paniculatus (*Amarant.*)
aroemen, Amaranthus spinosus (*Amaranth.*)
aroem gara, Coleus atropurpureus (*Lab.*)
asoe-asoe, Setaria flava (*Gram.*)
banban, Donax cannaeformis (*Marant.*)
banban belok, Phrynium parviflorum (*Marant.*)
bantjir, si bantjir, Cyrtandra sp. (*Gesn.*)
baur, Algaia eximia (*Meliac.*)
bĕrani, si bĕrani, Cyathula prostrata (*Amaranth.*)
bĕrasan, bĕras-bĕras, Sida retusa (*Malv.*)
bĕras-bĕras, * Sida rhombifolia (*Malv.*)
bernaik, Vernonia arborea (*Comp.*)
bĕsi-bĕsi, Justicia Gandarussa (*Acanth.*)
binara, Artemisia vulgaris (*Comp.*)
binbinĕn, Clitoria ternata (*Leg.*)
boeloeng-boeloeng tawar, * Mollugo verticillata (*Aiz.*)
boeloeng ramboeng, * Tarenna mollis (*Rub.*)
boenga rih, * Imperata cylindrica (*Gram.*)
boenga rinte, Coelogyne sp. (*Orch.*)
boenga sapa, boenga sapa-sapa, Impatiens sp. (*Balsam.*)
boenga simpa, Plumiera acutifolia (*Apoc.*)
boengkai, Solanum indicum (*Solan.*)
boengkai rimbang, * Solanum torvum (*Solan.*)
dajang, * Chasalia curviflora (*Rub.*)
dawa, Andropogon Sorghum (*Gram.*)
dawan tahoen, not identified.

děreng-děreng. Hyptis suaveolens (*Lab.*)
dilah antoe ara, Antrophyum callifolium (*Polypod.*)
djaba, Eleusine corocana (*Gram.*)
djaoeng-djaoeng, djaoengen, Ixora salicifolia (*Rub.*)
djaong-djaong, * Ixora salicifolia (*Rub.*)
djarikdjak, Lycopodium cernuum (*Lyc.*)
djaroem-djaroem, Tarenna mollis (*Rub.*)
djĕrring, Pithecolobium jiringa (*Leg.*)
doekoet-doekoet, * Eragrostis unioloides (*Gram.*)
galinggang, Cassia occidentalis (*Leg.*)
galoenggoeng, Blumea balsamifera (*Comp.*)
gamber-gamber, Desmodium virgatum (*Leg.*)
gambor-gambor, Desmodium lasiocarpum (*Leg.*)
gamboet, Panicum indicum (*Gram.*)
gĕning-gĕning, Sauropus cf. forcipatus (*Euph.*)
gĕrat-gĕrat, Cosmos caudatus (*Comp.*)
goeak, Flemingia strobilifera (*Leg.*)
hoeboeng-hoeboeng, Sida corylifolia (*Malv.*)
ikor-ikor, Acalypha hispida (*Euph.*)
inggir-inggir, Clitoria ternata (*Leg.*)
inggir-inggir, * Crotalaria Saltiana (*Leg.*)
kalindjoehang, Taetsia (Cordyline) fruticosa (*Lil.*)
kapal-kapal, Bryophyllum pinnatum (*Crass.*)
kapal-kapal kĕrangen, Solanum biflorum (*Solan.*)
kapias, = kapias rih, Bromheadia sp. (*Orch.*)
katjar, * Impatiens balsamea (*Balsam.*)
katji rah-rah, gen. & sp. indet. (*Orch.*)
kĕlempen, Eurya acuminata (*Theac.*)
kĕrakap, Ficus parietalis (*Mor.*)
kĕrangen, *see* kapal kapal kĕrangen
kĕrpe baloe, waren kĕrpe baloe, Tetrastigma sp. (*Vit.*)
kĕrsap, *see* ling kĕrsap
kĕtĕp-kĕtĕp mentji, Ficus subulata (*Mor.*)
kĕttang, * Daemonorops oblongus Mart. (*Palm.*)
kimboe-kimboe, * Callicarpa arborea (*Verb.*)
kisik, Panicum palmaefolium (*Gram.*)
koadji, Ardisia sanguinolenta (*Myrsin.*)
koedin-koedin, gen. & sp. indet. (*Malv.*)
koendĕlen pamal, Cipadessa baccifera (*Meliac.*)
koepi-koepi, Rubus alceaefolius (*Rosac.*)
koepikoepian, Rubus moluccanus (*Rosac.*)
koermil, Oplismenus compositus (*Gram.*)
lenggas, * Leucas zeylanica (*Lab.*)
lĕngnga, Sesamum orientale (*Pedal.*)
leoeh, * Physalis angulata (*Solan.*)
ling kĕrsap, Schefflera sp. (*Aral.*)
mbĕttak, Melochia umbellata (*Sterc.*)
mentji, *see* kĕtĕp-kĕtĕp mentji
nakan bĕnang, Alyscicarpus vaginalis (*Leg.*)

nangkat-nangkat, * Macaranga tanarius (*Euph.*)
nderasi, Oreocnide nivea Merr. (*Euph.*)
nderroeng, * Trema orientalis (*Ulm.*)
ndiwah, Grewia paniculata (*Til.*)
ndoepar, gen. & sp. indet. (*Leg.*)
oeban-oeban, si oeban-oeban, Tarenna sp. (*Rub.*)
padang sambo, Andropogon intermedius (*Gram.*)
padang sambo, Andropogon serratus var. nitidus (*Gram.*)
padang tegoeh, * Eleusine indica (*Gram.*)
paia, *see* toeba paia
pakoe, Microlepia platyphylla (*Polypod.*)
pakoe koening, * Dryopteris sagittifolia (*Polypod.*)
pamal, *see* koendělen pamal
pěldang, Cyclophorus sp. (*Polypod.*)
pěldang radja, Dendrobium sp. (*Orch.*)
pěrbentjil, * Leea indica (*Vit.*)
perik, *s e* tjeptjep perik.
pěssel, Adenostemma lavenia (*Comp.*)
pidjer keling, * Urena lobata v. scabriuscula (*Malv.*)
pidjer keling, Triumfetta tomentosa (*Til.*)
pildang, = pěldang
piso-piso, Belamcanda chinensis (*Irid.*)
poeltok-poeltok, * Physalis angulata (*Solan.*)
ramboeng, *see* boeloeng ramboeng
rěkat, Spathiglottis plicata (*Orch.*)
riang-riang, Begonia sp. (*Begon.*)
rih, *see* boenga rih
rimba tasik, Clerodendron serratum (*Verb.*)
rinte, *see* boenga rinte.
ritik rias, Cajanus Cajan (*Leg.*)
roekoe-roekoe, * Heliotropium indicum (*Borag.*)
roengkas, = si roengkas
sajat-sajat, Scleria sumatrensis (*Cyp.*)
salagoendi, Vitex trifolia (*Verb.*)
sampe loeloet, * Urena lobata (*Malv.*)
sapa, sapa-sapa, *see* boenga sapa
sari pěgěk, Bidens pilosa (*Comp.*)
sělando, Sambucus javanica (*Caprif.*)
sělantan, Graptophyllum pictum (*Acanth.*)
sěmpalingen, Sumbaviopsis albicans (*Euph.*)
sěnděp-sěnděp, Equisetum debile (*Equiset.*)
sendoedoek, * Melastoma polyanthum (*Melast.*)
sereme, * Phyllanthus sp. (*Euph.*)
ser-ser, Erigeron linifolius (*Comp.*)
si bantjir, Cyrtandra sp. (*Gesn.*)
si bĕrani, Cyathula prostrata (*Amaranth.*)
simpalis, * Pogonatherum paniceum (*Gram.*)
singkoet, Nieuwiedia veratrifolia (*Orch.*)
singkoet, * Calanthe veratrifolia (*Orch.*)

si oeban-oeban, Tarenna sp. (*Rub.*)
sira-sira, gen. & sp. indet. — abnormal
siro, Cudranea javanensis (*Mor.*)
si roengkas, Mikania scandens (*Comp.*)
si tamtam, Trichosporum sp. (*Gesn.*)
si tĕloe-boeloeng, Evodia sp. (*Rut.*)
si tĕpoe, Pseuderanthemum sp. (*Acanth.*)
si tottot, Strobilanthes sp. (*Acanth.*)
soerindan, * Loranthus ferrugineus (*Lor.*)
tada-tada, Trevesia Burkei (*Aral.*)
takor-takor, Nepenthes cf. mirabilis (*Nepent.*)
taloe dagang, Ageratum conyzoides (*Comp.*)
tamtam, si tamtam, Trichosporum sp. (*Gesn.*)
taratinggi, Lycopodium Phlegmaria (*Lycop.*)
tawar, *see* boeloeng-boeloeng tawar
tĕllep, Indigofera tinctoria (*Leg.*)
tĕloe-boeloeng, si tĕloe-boeloeng, Evodia sp. (*Rub.*)
tengkoea, * Commelina nudiflora (*Commel.*)
tĕpoe, si tĕpoe, Pseuderanthemum sp. (*Acanth.*)
teriktik, * Euphorbia hirta (*Euph.*)
tĕrleng, Ophiurus exaltatus (*Gram.*)
tinggĕrĕn, Desmodium gyrans (*Leg.*)
tjaloeng-tjaloeng, Viola Patrinii (*Viol.*)
tjapĕt, Macaranga triloba (*Euph.*)
tjeppira, Dubregeasia longifolia (*Urt.*)
tjeptjep perik, Ardisia sp. (*Myrsin.*)
tjingkerroe, Coix lachryma-Jobi (*Gram.*)
tjipa-tjipa, Firmiana colorata (*Sterc.*)
toeba paia, * Polygonum barbatum (*Polygon.*)
toeba pajan, Polygonum barbatum (*Polygon.*)
toeba sira, * Mallotus philippinensis (*Euph.*)
tongkil begoe, Dendrobium sp. (*Orch.*)
tongkil-tongkil, gen. & sp. indet. (*Orch.*)
warĕn, Gynostemma laxum (*Cucurb.*)
warĕn kĕrpe baloe, kĕrpe baloe, Tetrastigma sp. (*Vit.*)

University of Michigan

# SOME PORIAS FROM THE REGION OF THE LAKE STATES

DOW V. BAXTER

THE importance of the wood-decaying fungi in the timber lands of the Lake States is becoming more and more appreciated. A review of the literature which deals with the fungus flora of this area, however, discloses the fact that relatively little attention has been given to the occurrence of the genus Poria in this region.

Overholts (1) has reported *Poria ambigua* Bres. and *P. ferruginosa* (Schrad.) Fr. from Ann Arbor and New Richmond, Michigan. He (2) lists *Poria semitincta* (Pk.) Cook, from Wisconsin. In *North American Flora* Murrill (4) has given descriptions of four porias found in Michigan, Wisconsin, or Ohio. In another publication (5) he describes *Poria Dodgei* Murr. as a new species from Algoma, Wisconsin. Neuman (7) enumerates twenty-seven porias from this region, but the identity of many of these plants is in doubt. Weir (8) has reported *P. papyracea* (Schw.) Cke. on Thuja from Wisconsin and Michigan. Bresadola (9) has described *Poria proxima* Bres. collected by Weir on hickory in Indiana.

In the following account, no attempt has been made to discuss all the plants collected by the writer during the last few years in Michigan and in Wisconsin. Many plants, such as those belonging to *Poria mucida, P. sinuosa, P. mollusca* and certain other groups, are purposely omitted from this report. Numerous others await further comparisons before their identity can be learned.

I desire to express my appreciation to Dr. L. O. Overholts, Dr. James R. Weir and Professor Lars Romell for their kindness in identifying several specimens referred to them for study, and

to Dr. J. J. Davis for his generosity in permitting me to study the plants in the Wisconsin University Herbarium. Comparisons have been made with plants identified by Bresadola, Peck and other mycologists; such plants being found chiefly in the University of Wisconsin and the University of Michigan herbaria. It has been found necessary to follow my own interpretation of many of the plants here reported and I therefore assume full responsibility for all errors in identification.

*Poria ambigua* Bres. — Usually found broadly effused on the bark or wood of oak stumps or logs. Although an abundant production of spores seems to be characteristic for this plant, cultures of the fungus, prepared in a manner similar to that described for *Fomes fraxineus* (10), have not shown even an indication of tube formation within a four months' culture period. (See Pl. VI, Fig. 2.)

*Poria attenuata* Pk. — Commonly found on bark and sticks of both poplar and oak. Ann Arbor, Michigan; Madison, Wisconsin. Plants with a white somewhat pubescent border less than 0.35 to 0.65 mm. wide. Thin subiculum very distinct, 0.3 to 0.4 mm. wide; tubes averaging 0.5–0.75 mm. long, mouths 'pale ochraceous-buff,' 'pinkish cinnamon,' 'vinaceous-cinnamon' to 'cinnamon' (Ridg.). Pore mouths of the Madison plants average 4 to 6 per millimeter. Abundant encrusted cystidia, 12–65 × 5–9 $\mu$. Hyphae hyaline, seldom branched, 1–3.6 $\mu$ wide.

*Poria betulina* Murrill. — Common on fallen and standing dead birch in Michigan and Wisconsin. Plants with tomentose, tawny olive margins. Pore mouths 'snuff brown' (Ridg.). Hyphae 2–4 $\mu$ wide, brown except a few hyaline strands which may stuff the tubes. Brown cystidia present.

*Poria Blytii* Fr. — Specimen in Wisconsin University Herbarium. *Fide* Bresadola. Tubes dark 'purple-drab' (Ridg.), 3–5 mm. long, mouths 2–5, mostly 4–5 per millimeter, 'sayal brown' (Ridg.) subiculum distinct up to 1 mm. thick, spores ellipsoid, 2.4–3.6 × 1 $\mu$; not found attached; measurements are, therefore, of doubtful value.

*Poria callosa* = *Trametes serialis* Fr.

*Poria candidissima* (Schw.) Cooke. — On cedar log. Keweenaw Bay, Michigan.

*Poria crassa* Karst. — This plant is in the University of Wisconsin Herbarium. *Fide* Bresadola. Through the kindness of Professor Romell, I have received a fragment of this plant sent to him by Karsten. Though the hyphae of the Wisconsin plant are very slightly smaller than those of the European plant, it seems that this collection might be referred to *Poria crassa.* The hyphae of the Wisconsin specimen and that of Karsten's plant have, however, the same variation in width, namely 1–4 $\mu$. Unfortunately our specimen is sterile and so it is impossible at this time to make a definite record of the recurrence of this plant in the Lake States.

*Poria ferruginosa* (Schrad.) Fr. — On *Amelanchier canadensis.* Hancock, Michigan; *Fraxinus nigra,* McMillan, Michigan; and elsewhere in this region. Most commonly found on hardwoods though it has been collected on hemlock in Wisconsin. (A specimen on conifers, *fide* Overholts.)

*Poria inermis* Ell. & Ev. — Commonly found in Michigan in tamarack swamp areas. This plant has been collected only on *Ilex verticillata* in the state.

*Poria lenis* Karst. — On white pine. Devil's Lake region, Wisconsin. Irregularly effused over the log up to lengths of fourteen inches or more, 0.35 to 2 mm. thick, of light weight, with or without a broadly sterile white margin (one inch or more); subiculum white, 0.35 mm. or less in thickness, tubes white to 'pinkish buff' (Ridg.) conformed to the substratum, not stratified, tubes 1 to 1.65 mm. long. Mouths 3–4, mostly 4 per millimeter, with fimbriate margin. Spores allantoid $4 \times 1$ $\mu$, hyphae undulate, mostly 2.4 but ranging 1.2–3.6 $\mu$ wide, crystals present, frequently at ends of hyphae or occurring in mounts.

*Poria lenis* may be confused with *Polyporus sericeo-mollis,* which is also found on conifers in the Lake States. None of the collections of *Poria lenis* show reflexed margins; this habit is particularly characteristic of the dried specimens of *Polyporus sericeo-mollis.* The fringed pore mouths and the somewhat smaller hyphae of *Polyporus lenis* are also distinctive.

Because of the very rotten condition of the wood on which *P. lenis* has been found, the actual type of decay produced by this fungus is uncertain. That other fungi are present on such logs is more than likely; their effect upon the wood may be more or less striking and they may produce the type of rot usually found accompanying the fruiting bodies of this poria.

The several collections of decayed wood on which this fungus has been found are characterized, first of all, by the abundant occurrence and copious growth of a white woolly mycelium which grows over the surface and fills the cracks in the rotten wood. It is found growing between the annual rings and is strikingly visible here if the rings are separated and the wood pulled apart with the fingers. The dried, fragile wood is very light in weight. In tangential section, the wood appears to be finely honeycombed with narrow, irregular pockets which follow the grain of the wood. These pockets may be microscopic, measuring $61 \times 37$ $\mu$ or smaller up to macroscopically visible pockets 25 mm. long and mostly 0.5–1 mm. wide. These pockets are formed by the breaking down of one to five or sometimes more tracheid walls. The thin-walled and sparsely septate branched mycelium frequently fills these pockets and forms mats which may be seen by the naked eye. As in the case of *Polyporus sericeo-mollis*, all the decayed wood collections show cubical blocks similar to those resulting from the transverse, tangential and radial splitting caused by *Polyporus Schweinitzii* Fr. in coniferous wood. Whether this rot is the result of the activities of the fungus in question is not known.

*Poria medulla-panis* (Jacq.) Pers. — Most commonly found on Quercus, Hicoria and Prunus in the Lake States.

*Poria pulchella* Schw. — Bresadola, Murrill (6) and Overholts (3) have indicated that this plant may be the same as *Poria medulla-panis*. That they are closely related, if not the same, is indicated by the many collections found in southern Wisconsin. Plants growing on the same log vary from the white form to 'buff-yellow' to 'ivory yellow' (Ridg.); the color apparently depends upon the exposure of the plant to light.

*Poria punctata* Fr. = *Poria Friesiana* Bres., *Poria laminata*

Murr. (Pl. II). This plant is one of the most common porias of the region; found on various deciduous trees such as willow, maple, hornbeam, and papaw.

Wood of *Ostrya virginiana* destroyed by this fungus becomes whitish as it dries out. It crumbles readily between the fingers and falls away as a material resembling coarse sawdust. The very small pieces of wood which remain intact are riddled by the action of the fungus.

Although the mycelium may be found in all the elements of the rotten wood, the hyphae do not occur abundantly in the badly decayed areas which are not located directly beneath the fruiting body. The mycelium in the wood consists of small hyaline hyphae which branch freely. In the willow wood, the vessels are filled with this mycelium, which varies in width from less than 1 micron — and the most of the hyphae are less than 1–2.2 $\mu$ in thickness. No swellings of the hyphae occur where the mycelium passes from one cell into another. The hyphae in the *Ostrya virginiana* wood seem to grow from one cell into another through bore holes as well as through the bordered pits, and show very slight or no enlargements on either side of the pits in the most rotten wood. The mycelium in papaw wood is mostly hyaline, though it is faintly brown in some of the vessels, and is more variable than the hyphae observed in the other woods as regards the general uniformity in thickness. In the papaw wood, the mycelium measures 1–2.4 $\mu$ wide. Brownish deposits, "decomposition products," are found largely in the rays and to some extent in the wood fibers of the papaw. Likewise, this brown substance usually occurs in the medullary rays and frequently marks the ring growth in the decayed willow wood. After five days of treatment, hydrochloric acid has little or no effect upon the "decomposition products" in either of these two woods, but the brown substance is readily dissolved by nitric acid within this period.

*Poria purpurea* Fr. — On oak. This specimen is in the Wisconsin University Herbarium. *Fide* Bresadola. Bresadola states on the label that this plant is identical with European specimens and that it may also be *Poria cruentata*. Morgan identi-

fied it as *Polyporus cruentatus* Mont. Plant 'snuff brown' to 'natal brown'–'chestnut-brown' (Ridg.). Pore mouths 1–3 per millimeter, tubes 0.5–1 mm. long, plant 1 mm. thick, subiculum indistinct; less than 0.35 mm. Spores hyaline, allantoid–ellipsoid, 4–6 × 1–2 $\mu$, averaging 5 × 1 $\mu$; not attached to basidia; measurements are, therefore, of doubtful value. Hyphae mucedinous, mostly hyaline, 1–5 $\mu$ wide, mostly 3 $\mu$.

*Portia semitincta* (Peck) Cooke. — This plant is found usually on badly decayed wood and bark of oak in southern Wisconsin. Margin of plant light 'purplish vinaceous,' tubes 'cream-buff' (Ridg.). The pores are unequal in size and number, 2–4, mostly 3 to a millimeter. Hyphae are hyaline, sometimes encrusted, 2–5 $\mu$ in diameter. Spores are cylindric, 4–5 × 1–2 $\mu$.

*Poria sericeo–mollis* Romell. — On conifers. Devil's Lake, Wisconsin. *Fide* Romell. Pore mouths 3 to a millimeter; tubes 1–2.5 mm.; hyphae 1–4, averaging about 3 $\mu$ wide. See *Poria lenis*.

*Poria spissa* (Schw.) Cooke. — This plant is commonly found on black ash in Michigan, though it has been collected on other deciduous hosts. Plants in this region when fresh are 'capucine yellow' to 'mars orange' (Ridg.)

*Poria subacida* Pk. (Pl. I, Figs. 3–4; Pl. III) — This poria is widely distributed throughout the coniferous districts of the Lake States. In southern Wisconsin, it is commonly found in the Devil's Lake, the Dells, and Parfrey's Glen regions. Though it may be collected on tamarack, pine, or almost any conifer, it usually occurs on hemlock. Birch is the usual deciduous wood on which it grows, though it has been found on elm in this state. It is not uncommon to find the fruiting body of this poria forming large sheets on dead standing trees or stumps as well as on fallen logs.

There are four specimens of this plant in the University of Wisconsin herbarium which have been identified by Peck (Pl. IV). One of these specimens, collected at Crandon, Wisconsin, on pine, has dried so that the tubes and pore mouths are now 'chestnut-' to 'buckthorn brown' (Ridg.). The plant is somewhat resinous in general appearance. Pore mouths 1–4, mostly 2–3 per millimeter; tubes 2–3 mm. long; hyphae hyaline,

1.2–4, mostly 2.4 $\mu$ wide; cystidia present; spores (in hundred lot) 4–6 × 2.4–4 $\mu$, averaging 4.5 × 3.5 $\mu$.

In the other Crandon specimen the tubes and pore mouths have dried to 'pale yellow-orange' (Ridg.). Pore mouths 2–3 per millimeter; tubes 3–4 mm. long; subiculum 0.5–0.75 mm. wide; spores (in hundred lot) 4–5.5 × 2.4–4 $\mu$, averaging 4 × 3 $\mu$.

The tubes and pore mouths of the Parfrey's Glen specimen have dried to 'pinkish buff' (Ridg.). Tubes 3–9 mm., averaging 4 mm. long; mouths 2–3 to a millimeter, subiculum conspicuous, averaging 0.35–0.5 mm. wide, hyphae colorless, 1–4, mostly 2 $\mu$ wide; spores (in hundred lot) 4–6 × 2.4–4, averaging 6 × 3.5 $\mu$.

The Ladysmith plant has dried so that the tubes are now russet, and the pore mouths 'pale ochraceous–buff' (Ridg.). Pore mouths 1–3 to a millimeter; tubes 3–4 mm. long; subiculum 0.5–1 mm. thick; spores (in hundred lot) 4–5.5 × 2.4–4, averaging 5 × 3.5 $\mu$.

The decay produced in hemlock by this fungus is similar to that described by Von Schrenk (11) for spruce. The badly decayed wood is spongy when wet, and, if in small pieces, upon drying appears as frayed papery shreds. The annual rings of larger pieces of decayed hemlock may be readily separated into concentric rings. Black spots, varying from 1 to 5 mm. long and less than 0.35–0.5 mm. wide, appear in both the early and later stages of the decay. A brownish decomposition product present in both the tracheids and rays forms these spots. These blackened areas may be surrounded by an irregular white region which gives a distinct blue color when treated with chloriodide of zinc. Mycelium occurs abundantly within and in the vicinity of the black spots as either fine hyaline hyphae which measure 1 $\mu$ or less in width or as irregular hyaline or brownish strands which vary in width to 3.6 $\mu$. Clamp connections are frequently found on this mycelium in the decayed wood.

*Poria tsugina* Murr. Common on fallen hemlock logs, Dells of the Wisconsin River. (See Pl. I, Figs. 1–2; Pl. V; Pl. VI, Fig. 1.)

Tangential sections of the wood rotted by this poria are characterized by a white mottled appearance in the early stages

of decay. This mottled effect is produced by the occurrence of white areas at first scattered throughout the summer wood. As the rot progresses, these areas increase in size and the remaining cells, decayed to a lesser degree, may then appear as small irregularly scattered brown spots. In radial section, white lines or zones may be observed in the summer wood region as a result of a continued coalescing of the white areas. The tracheids and ray cells here turn blue when treated with chloriodide of zinc. The white areas completely or almost completely separate the annual rings. There is then a tendency for the hemlock wood to break into flat pieces upon drying or under pressure; the slabs correspond to the annual rings.

Fine and much-branched hyphae, which measure less than 1 $\mu$ in width, occur in these broken-down regions. The hyphae of this poria vary in culture from their general appearance in decayed wood. On a malt extract medium (prepared in a similar way to that already referred to under *Poria ambigua*), the hyphae are not as uniform in width as those in the rotten wood. In culture, they vary from 1 $\mu$ to the larger-sized and more or less bulbous portions, which measure 5.5 $\mu$ in width. The hyphae ends and portions of the individual cells are frequently swollen; the swollen parts become occasionally chlamydosporic in appearance. These much-branched and many-septate hyphae may be hyaline or brown.

The mycelium in culture flasks is light buff in young cultures, and varies from this color to 'yellow ocher' and 'buckthorn brown' (Ridg.) in one-year cultures. The mycelium of *Poria tsugina* did not grow over all the wood during one-year hemlock-block cultures, but either formed brownish and somewhat rhizomorphic strands or grew out from the sides and ends of the blocks as white or buff-colored mycelium.

The mycelium in culture flasks discolored the malt extract agar by changing it to a dark brown. This color was the same as that of the dark lines in the form of circles or rings which may be frequently observed in decayed hemlock wood. The brownish substance, "products of decomposition," occurs both in the ray cells and in the tracheids. Sections of one-year-old culture

blocks of hemlock wood, however, did not reveal any such dark lines similar to those just mentioned.

*Poria undata* (Pers.) Bres. — This poria is frequently found in Michigan on black ash; the fruiting body forms large sheets over the fallen logs.

University of Wisconsin

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## DESCRIPTION OF PLATES

### PLATE I

FIG. 1. Hemlock wood rotted by *Poria tsugina* Murr. Section showing brown zone region. Drawing made with Bausch-Lomb microprojector

FIG. 2. *Poria tsugina* mycelium as it appeared in a one-year-old culture

FIG. 3. Hemlock wood rotted by *Poria subacida* Pk. Section showing enlarged black area. These areas or spots are characteristic features of hemlock rotted by this fungus. Drawing made with Bausch-Lomb microprojector

FIG. 4. Birch wood decayed by *Poria subacida* Pk. Drawing made with Bausch-Lomb microprojector

### PLATE II

*Poria punctata* Fr. and decayed wood of *Ostrya virginiana*

### PLATE III

*Poria subacida* Pk. on hemlock. Note the black spots which appear on wood where the bark has been removed

### PLATE IV

*Poria subacida* Pk. Plants *fide* C. H. Peck. Upper left, Crandon, Wisconsin; lower left, Crandon, Wisconsin; upper right, Ladysmith, Wisconsin; lower right, Parfrey's Glen, Wisconsin

### PLATE V

*Poria tsugina* Murr. on hemlock. There have been collected in Wisconsin specimens of this plant which show fourteen tube layers

### PLATE VI

FIG. 1. *Poria tsugina* Murr. on malt extract medium. The marginal growth of the fungus in cultures or the growth of the fungus on a somewhat dried medium resembles that of the old layers of fungus growth in the fruiting bodies

FIG. 2. Four months' culture of *Poria ambigua* Bres. on malt extract agar

PLATE I

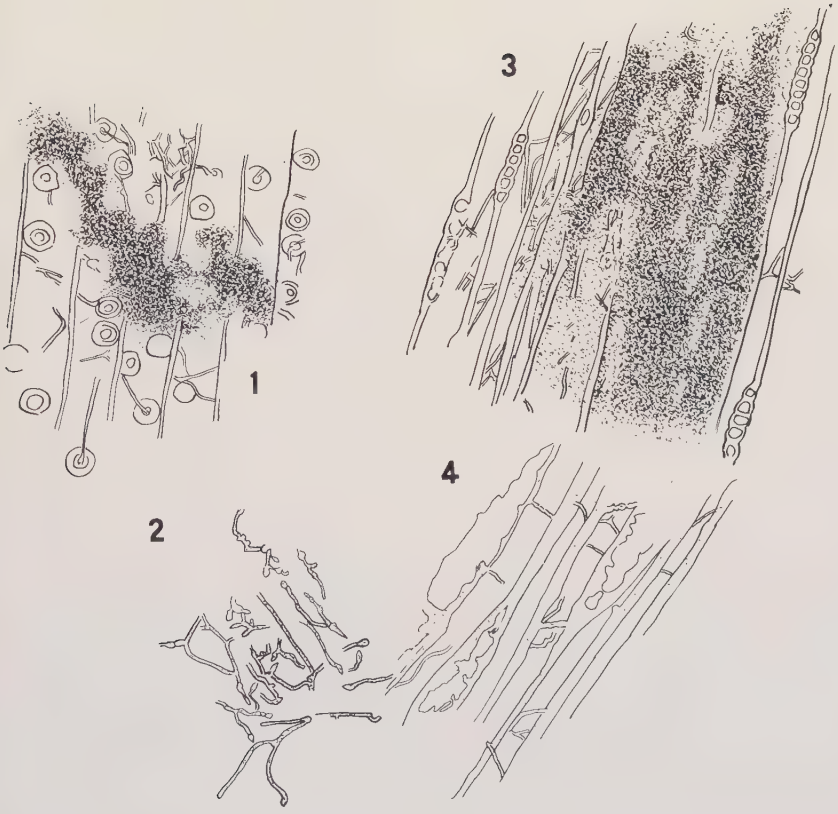

PLATE II

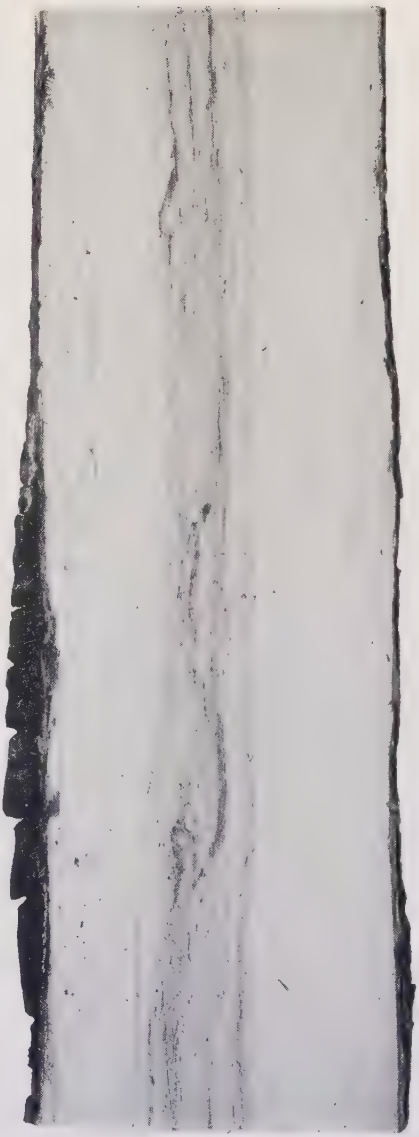

PLATE III

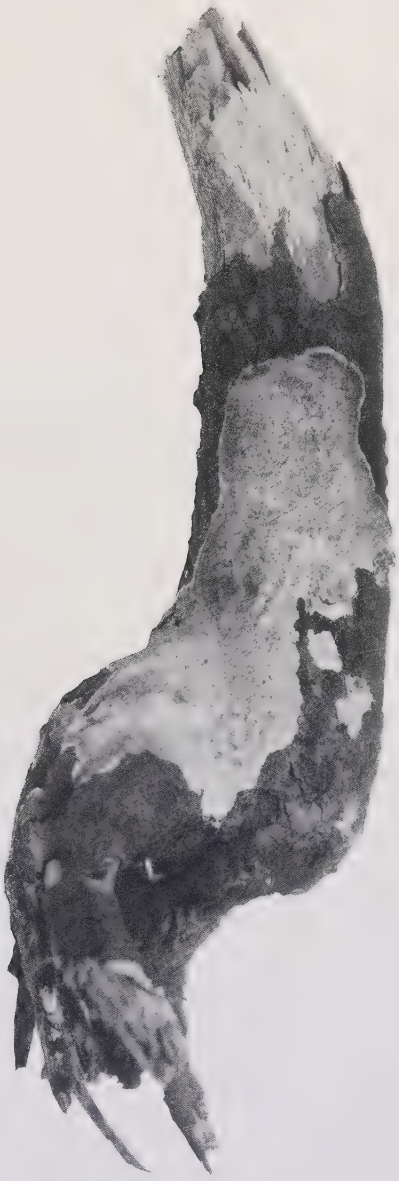

PLATE IV

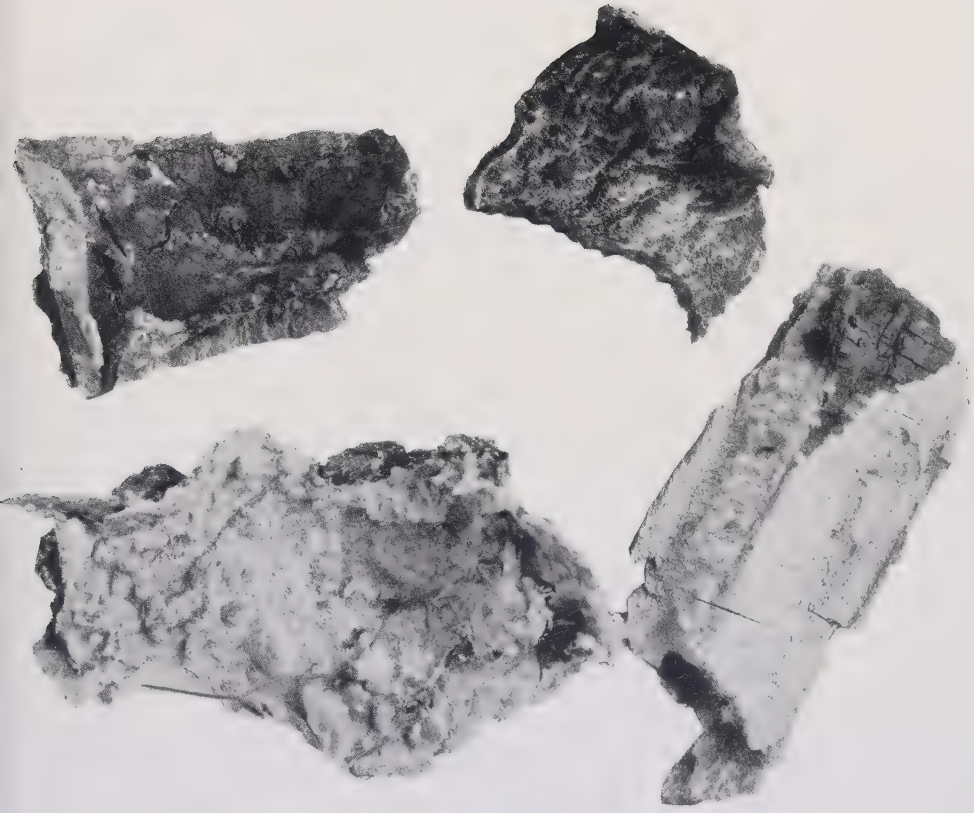

PLATE V

PLATE VI

FIG. 1

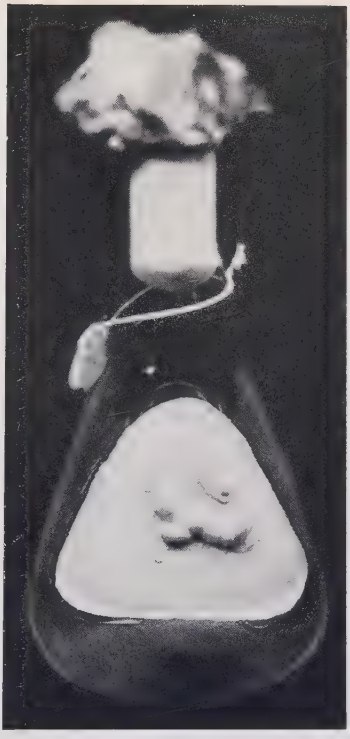

FIG. 2

# THE INHERITANCE OF RED BUD COLOR IN CROSSES OF *OENOTHERA PRATINCOLA* AND RELATED FORMS*

FRIEDA COBB BLANCHARD AND HARLEY HARRIS BARTLETT

Introduction
- Heterogametism
- Whole-chromosome cross-overs
- Freely segregating chromosomes
- The sex limitations of alpha and beta
- Earlier statements of the alpha-beta hypothesis

The inheritance of red bud color
- The character studied
- Forms used in the experiment
- Statement of the results and the proposed explanation
- Questionable points in the tables
- Summary of the conclusions as to bud color

The bearing of the results on other problems
- Plants of alpha-alpha constitution
- Plants of beta-beta constitution
- Metaclinic plants
- White and "lethal" seedlings

Literature cited
Explanations applying to all the tables
Tables

## INTRODUCTION

WE HAVE been able to explain the results of our experiments with Oenothera only on the hypothesis, propounded several times before, that most of the species and mutations are heterozygous, but heterozygous in an unusual way. We have used the term heterogametic in order to emphasize the difference from the usual type of heterozygosis. With apparently few exceptions, each plant is the result of the union of two unlike gametes, and in its turn produces the same two

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types of gametes. These two types, however, do not necessarily both occur as functional eggs and functional sperms. In some species of Oenothera, notably *Oe. pratincola*, a plant usually produces eggs exactly like the egg from which it originated, and pollen grains genetically exactly like the sperm which entered into its own zygote.

There are two very striking general rules in the behavior of the genus Oenothera: (1) The two different gametic combinations of chromosomes remain intact, and come from the plant just as they entered into it. (There is no interchange of chromosomes or parts of chromosomes, except when a mutation is produced.) (2) With few exceptions, functional eggs have the same genetic composition as the egg that produced the parent, and functional pollen is like the pollen that produced the parent. (There are apparently more exceptions to the second rule than to the first.) Moreover, the gamete generally functioning as an egg, which we call the $\alpha$ gamete, is homologous throughout a group of closely allied species and mutations; and the gamete generally functioning as a sperm, called the $\beta$ gamete, is almost identical throughout the same group.

A considerable group of allies of *Oe. pratincola* have been in culture now for a number of years. Most of them originated directly from *Oe. pratincola* by mutation, but a few have arisen in hybrid cultures of this species or its immediate derivatives. The results of almost every possible cross within the entire group of forms have shown that the characteristics of each type are in general determined by the $\alpha$ gamete. The $\beta$ gametes are in general alike throughout. We have found very few characteristics which are affected by the $\beta$ gametes: namely, bud color, color of the axis of the inflorescence near the apex, viscid pubescence of the buds, and revoluteness of the leaves. Attention is therefore being focused, for the present, upon this group of characteristics. The present paper deals with bud color. In order that the data may be considered by the reader in their proper setting, it has seemed necessary to discuss the hypothesis of heterogametism at some length.

*Heterogametism*

Within the group of *Oe. pratincola* each type is distinguished by a coherent assemblage of characteristics, which pertain to the $\alpha$ gamete, exclusive of the chromosomes which we refer to below as the freely segregating chromosomes. Thus, it has been found after years of experience with *Oe. pratincola* and the closely allied *Oe. numismatica*, two species which occur together at Lexington, Kentucky, that the two are always clearly distinct. If crossed, reciprocally, the progenies yield types that are indistinguishable from *Oe. numismatica* on the one hand, and *Oe. pratincola* on the other, except that the latter type, in hybrid progenies, has the viscid pubescence on the buds that is typical of *Oe. numismatica*, but not of *Oe. pratincola*. All the distinguishing features of *Oe. pratincola*, except the lack of viscid bud pubescence, are determined by the $\alpha$ gamete, just as all the features of *Oe. numismatica*, except the presence of viscid pubescence, are determined by the $\alpha$ gamete. It would be easy to multiply examples drawn from the hybridization of other wild types, but they would merely illustrate similar facts over and over again.

For an instance of types in which the $\alpha$ gamete carries all the distinguishing characteristics of a species and its mutations, the reader is referred to a paper on *Oe. Reynoldsii* by La Rue and Bartlett (1917).

Among the mutations of *Oe. pratincola* there is one which, as it originated, could not be distinguished from *Oe. Reynoldsii* except by bud color. On this account it was named mut. *simulans*. It may be modified, by appropriate crosses, as to color of buds (red *vs.* green), flatness of leaves (flat *vs.* revolute) and color of the axis at the apex of the inflorescences (red *vs.* green). Modification of bud pubescence is likewise possible. The dissociable features of mut. *simulans* are all features with which $\beta$ is concerned. The other numerous distinguishing characteristics of mut. *simulans* have so far proved inseparable from one another. They are linked in inheritance as though confined to a single chromosome.

*Whole-chromosome Cross-overs*

The *simulans* factor complex cannot be subjected to analysis by ordinary means — as far as we know there may be only one factor difference between *Oe. pratincola* and mut. *simulans.* Since the whole aspect of the two types is different, however, we are inclined to believe that whole chromosomes are probably concerned in the differences between parent types and such mutations as mut. *simulans,* even though the number of chromosomes remains unchanged.

According to this conception, mutations may take place by interchange of chromosomes between $\alpha$ and $\beta$. If this idea is correct, the number of such mutations for each species of Oenothera is limited, and since certain mutations recur time after time, it is not impossible that for such a species as *Oe. pratincola* a full set of them may eventually be obtained, the study of which will solve in large measure the peculiar problems presented by Oenothera genetics.

The characteristic group of $\alpha$ behaves as a single chromosome, and is responsible for a group of linked characters. We may get a break in this linkage of chromosomes by interchange of a chromosome pair between $\alpha$ and $\beta$, just as, in other organisms, we get a break in the linkage group of a chromosome by crossing-over. (Interchange of complete chromosomes between two groups of linked chromosomes, as opposed to "crossing-over" between parts of two chromosomes of a pair, would be indistinguishable.) Such an interchange of chromosomes might result in the formation of a plant having a pair of identical chromosomes, one in $\alpha$ and one in $\beta$. The acquisition by $\alpha$ of a $\beta$ chromosome should produce a change in the plant which would be inherited through the eggs of the mutation. A corresponding change in a $\beta$ gamete, by the acquisition of an $\alpha$ chromosome, should make a patroclinic mutation. The latter are not so common, perhaps because the factors in $\alpha$ are dominant and the presence of a second dose in $\beta$ makes no difference. $\beta$ factors for red bud color and red tips to branches probably did originate by a whole-chromosome cross-over.

It is conceivable that when once a chromosome becomes dissociated from $\alpha$ and replaced by the corresponding one from $\beta$, the pair, alike, are free, and the two chromosomes are thereafter interchangeable. If one of them is replaced through hybridization by a similar $\beta$ chromosome differing in a single character, Mendelian behavior would follow. This behavior would be expected to cease if the plant were crossed with one in which the chromosomes concerned were so different that the two were not interchangeable. There is some indication that this behavior actually occurs.

### *Freely Segregating Chromosomes*

In addition to the chromosome or set of chromosomes which we assume to be characteristic of the $\alpha$ or of the $\beta$ gamete, it is necessary to assume that there are sometimes one or more freely segregating pairs of chromosomes, the members of which occur interchangeably in functional eggs and sperms. Characteristics determined by factors in these freely segregating chromosomes would be expected to show Mendelian behavior. The single case which shows that such strictly homologous chromosomes exist is provided by the inheritance of the revolute-leaved *Oe. pratincola* mut. *formosa* (Cobb and Bartlett, 1919; Cobb, 1921).

The results so far obtained give no clue as to whether there are more than one pair of freely segregating chromosomes. As we have maintained from the first announcement of the alpha-beta hypothesis (Bartlett, 1916), it is conceivable that the characteristics of $\alpha$ and $\beta$ may be confined to single chromosomes, and not at all concerned with the six pairs of freely segregating chromosomes. Shull states that the chief difference between his view and ours is that he reduces the characteristic portions of the gametes to single chromosomes, assuming that we insist upon the existence of a group, although we have not done so. Thus he states (1923, p. 97) that by the substitution of "a single maternal or paternal chromosome" in place of "a distinctly maternal or distinctly paternal set of chromosomes" he has given a rational explanation for heterogametism. We

believe that our hypothesis, whenever stated, has been carefully worded to cover the single-chromosome idea.

Cleland has recently published several very significant and valuable papers on the cytology of Oenothera. He comments as follows (Cleland, 1923): "Shull finds that most of the characters that he has studied so far seem to belong to the same linkage group. He believes, therefore, that the genes for all of these characters are carried in the same chromosome pair. In view of the facts here presented, it seems to me that the possible correspondence of larger groups composed of several chromosomes, rather than of individual chromosome pairs, to character linkage groups such as Shull has discovered, should be kept in mind." It will be quite obvious that there are arguments for the idea of a set of linked chromosomes, and that from Cleland's point of view, our idea of heterogametism seems not irrational.

We actually favor the idea of a chromosome set, and believe that the number of chromosomes in the set may be capable of experimental alteration. Thus, the $\alpha$ group may come to consist of fewer chromosomes by being mated with a $\beta$ of which one chromosome is identical or essentially identical with a chromosome of the $\alpha$ group. A release of a chromosome from $\alpha$ or $\beta$ bondage may be accomplished by introducing an exact homologue into the zygotic complex.

### *The Sex Limitations of Alpha and Beta*

There are some regular exceptions to the rule that eggs are $\alpha$ gametes and sperms are $\beta$. Probably all the types related to *Oe. pratincola* produce occasional functional $\beta$ eggs and $\alpha$ sperms. There are types in which the eggs are all $\alpha$, and the pollen grains are of two kinds, $\alpha$ and $\beta$, in about equal numbers. Two types are known in which both $\alpha$ and $\beta$ eggs, and $\alpha$ and $\beta$ pollen grains occur.

Even when the supposed $\alpha$ and $\beta$ sets of chromosomes function indiscriminately as eggs or sperms, the assemblages of characteristics determined by $\alpha$ and by $\beta$ are not destroyed. As far as the chromosome complex is concerned, an $\alpha$ egg and an $\alpha$ sperm appear to be identical, and an individual of the

composition $\alpha\beta$ appears to be quite identical with one of $\beta\alpha$ composition.

By self-pollination of a form producing practically only $\beta$ pollen, the exceptional $\beta$ eggs are lost, for they must combine with identical $\beta$ sperms, and such a combination usually does not survive. Likewise, exceptional $\alpha$ pollen grains must generally be lost, if produced by a type that has few or no functioning $\beta$ eggs.

But by suitable hybridization the presence of exceptional gametes of both classes is shown, for the $\beta$ egg, if fertilized by a $\beta$ sperm slightly different from itself, will often produce a viable zygote. The same is true of the $\alpha$ sperm. If anomalous fertilizations take place in which the two $\alpha$ gametes are of a somewhat different origin, if for example, one comes from each of two mutations of *Oe. pratincola*, or one comes from *Oe. pratincola* and one from *Oe. numismatica*, the zygote may grow into a full-sized plant, and reproduce itself. An $\alpha\alpha$ plant seems to have a tendency toward sterility, though some combinations are sufficiently fertile after the earliest flowers have dropped, and are found to breed true.

The combination $\beta\beta$ also occurs, and it is also true of this combination that when the two gametes are identical the combination does not live, or, as in the case of one of our mutations from *Oe. pratincola* which produces $\alpha$ and $\beta$ eggs and $\alpha$ and $\beta$ pollen, makes a very weak dwarf plant, only three or four inches high, which never blossoms. But if the two $\beta$ gametes are slightly different, they may produce the largest, strongest and most striking plants in the garden.

Among *Oe. pratincola* and its mutations, $\alpha\alpha$ plants and $\beta\beta$ plants are recognizable at a glance. A considerable amount of experimenting has been done with these two classes of plants, and the results are being prepared for publication.

Anomalous $\beta$ eggs, if borne by a plant which is pollinated by a form producing both $\alpha$ and $\beta$ pollen, will have one chance in two of producing a $\beta\alpha$ combination, which is of course identical with the normal $\alpha\beta$ combination of the reciprocal cross. Such plants are very frequently encountered in the hybrid cultures, and are the metaclinic hybrids of De Vries (De Vries, 1913).

### *Earlier Statements of the Alpha-beta Hypothesis*

The statement of the alpha-beta hypothesis in earlier papers seems to have been overlooked or misunderstood by several workers. The references are as follows: Bartlett, 1916, p. 523 ff.; La Rue and Bartlett, 1917, p. 132; Cobb and Bartlett, 1919, p. 473 ff.; Cobb, 1921, p. 2 ff.; Klaphaak and Bartlett, 1922, p. 447 ff.

## THE INHERITANCE OF RED BUD COLOR

### *The Character Studied*

The red bud color with which this paper is concerned is confined to the cone, excluding the hypanthium and ovary. It covers the calyx segments except for the free tips and the midveins, which are green, and the lines along the four sutures of the segments, which are yellow. The cone of a mature bud of *Oe. pratincola* mut. *simulans*, the form in which the red bud character first appeared, is 'terra cotta' (of Ridgeway's *Color Standards*). On close examination it can be seen that this coloration is due to the clear bright red tubercular bases of certain hairs combined with the paler, and less intense, green-red of the surface of the cone. The tubercles at the bases of the hairs are not inherited with the red bud color: they remain linked with the other characteristics of mut. *simulans*. The red buds acquired by other forms, through crossing, therefore, have only the red ground color, not the red tubercles. These tuberculate based hairs are quite distinct from, and independent of, the viscid hairs of the short, dense, pubescence recorded in this paper as "viscid pubescence."

### *Forms Used in the Experiment*

The following species and mutations are involved in the crosses recorded in this paper:

*Oenothera pratincola*, Strains Lexington C and E (see Bartlett, 1915 *a*, 1915 *c*, 1916; Cobb and Bartlett, 1919; Cobb, 1921;

Klaphaak and Bartlett, 1922). — This form has green buds which lack viscid pubescence, and stems green to the tips of the inflorescences.

*Oenothera pratincola* mut. *nitidissima* (see Bartlett, 1915 *c*, p. 440 and Table IV; Cobb, 1921, p. 11 and Table I). — This mutation has green buds with viscid pubescence, and stems bright red to the tips of the inflorescences.

*Oenothera pratincola* mut. *strobilina*. — This mutation, not yet referred to in print, is like f. *typica* in the characters recorded in this paper, the differences being chiefly in plant form.

*Oenothera pratincola* mut. *simulans* (see Klaphaak and Bartlett, 1922, p. 449). — This mutation has red buds with viscid pubescence, and green stems.

*Oenothera numismatica* (see Bartlett 1915 *a*, 1916; Cobb, 1921, p. 22; Klaphaak and Bartlett, 1922, p. 448). — This species has green buds with viscid pubescence, and stems entirely green.

*Oenothera numismatica* mut. *substrobilina*. — This mutation, not yet referred to in print, is like f. *typica* as far as the characters recorded in this paper are concerned. It is known to be designated correctly, but it should be pointed out that it arose in a hybridized line. From pedigree 20, in Table I, it will be seen that a pure *Oe. numismatica* might have resulted in the pedigree from a $\beta\alpha$ plant of the first generation being crossed a second time with *Oe. numismatica*, and producing $\alpha\beta$. Thus the gamete of *Oe. pratincola* could be eliminated.

*Oenothera Reynoldsii* (see Bartlett, 1915 *b*; La Rue and Bartlett, 1917, 1918). — This species has green buds with viscid pubescence, and green stems.

All the forms listed differ from one another in additional characteristics with which we are not concerned in this paper.

### *Statements of the Results and the Proposed Explanation*

All strains of *Oe. pratincola* and all its mutations with the exception of mut. *simulans* have buds entirely green. Mut. *simulans*, which arose from strain C of *Oe. pratincola*, has buds the cones of which are bright deep-red with eight more or less

evident green or yellowish stripes, one at each mid-vein and one at each suture of the segments.

In crosses within the species *Oe. pratincola* it was observed that, while the inheritance of the general plant form is matroclinic, the inheritance of bud color is patroclinic, and that successive generations breed true to the bud color of the $F_1$ generation.

In the cross *Oe. pratincola* f. *typica* × mut. *simulans*, the $F_1$ is f. *typica* with the addition of the red bud color and the viscid pubescence of mut. *simulans*. It has not yet been determined whether any other flower character of mut. *simulans* is brought in by the pollen; possibly the length of the hypanthium of the $F_1$ generation is that of mut. *simulans* rather than that of f. *typica*. The hybrid has been called "pratincola with simulans flowers." The bud color and pubescence characters which are brought in by the pollen of mut. *simulans* are not linked, for the bud color breeds true, whereas the pubescence does not. In the $F_2$ and following generations there is a percentage, usually small, of plants with the pubescence of f. *typica*, i.e., without viscid pubescence.

The first explanation to suggest itself for the inheritance of the bud color is that it is determined by $\beta$ alone, and that there is no corresponding factor in $\alpha$. Since $\alpha$ and $\beta$ have become so different with their complete isolation from each other, it is conceivable that some factors of $\beta$ no longer have allelomorphs in $\alpha$. Another explanation which was considered is that the red bud color of mut. *simulans* is dominant, that all $\alpha$ gametes in *Oe. pratincola* and its mutations carry the recessive factor, for green buds, and therefore the bud color of the hybrid is that of the pollen parent.

But with the inclusion of *Oe. numismatica*, a closely related form, in the experiment, neither of these explanations would hold. *Oe. numismatica* has green buds, and, we have found, cannot have red buds even when pollinated by the red-budded mut. *simulans*. This eliminates the possibility of the dominance of red, also the possibility of $\beta$ alone determining the bud color.

An hypothesis which explains all the facts given above is that green bud color is dominant, red recessive; that mut. *simulans* carries the red factor in both $\alpha$ and $\beta$; that *Oe. pratincola* and all its other mutations carry the factor for red in $\alpha$ and the factor for green in $\beta$; and that *Oe. numismatica* carries factors for green in both $\alpha$ and $\beta$. The constitutions in respect to factors for bud color then, of the plants used in the crosses recorded in this paper, are:

| | alpha | beta |
|---|---|---|
| *Oe. pratincola* f. *typica* | red | green (heterozygous) |
| *Oe. pratincola* mut. *nitidissima* | red | green (heterozygous) |
| *Oe. pratincola* mut. *strobilina* | red | green (heterozygous) |
| *Oe. pratincola* mut. *simulans* | red | red (homozygous recessive) |
| *Oe. numismatica* f. *typica* | green | green (homozygous dominant) |
| *Oe. numismatica* mut. *substrobilina* | green | green (homozygous dominant) |
| *Oe. Reynoldsii* f. *typica* | red | green (heterozygous) |

With these constitutions in mind, further crosses and backcrosses were made, and the results verified this explanation. These results are given in Tables II to XLVI inclusive, which record the following crosses:

| TABLE | |
|---|---|
| II | *Oe. pratincola* f. *typica* × mut. *simulans* |
| III | $F_2$ to $F_7$ generations of preceding cross |
| IV | $F_2$ generation of preceding cross |
| V | *Oe. pratincola* mut. *nitidissima* × mut. *simulans* |
| VI | $F_2$ to $F_4$ generations of preceding cross |
| VII | *Oe. Reynoldsii* f. *typica* × *Oe. pratincola* mut. *simulans* |
| VIII | $F_2$ and $F_3$ generations of preceding cross |
| IX | *Oe. pratincola* mut. *simulans* × f. *typica* |
| X | $F_2$ to $F_4$ generations of preceding cross |
| XI | *Oe. pratincola* mut. *simulans* × mut. *nitidissima* |
| XII | $F_2$ generation of preceding cross |
| XIII | *Oe. pratincola* mut. *simulans* × *Oe. Reynoldsii* f. *typica* |
| XIV | $F_2$ generation of preceding cross |
| XV | *Oe. numismatica* f. *typica* × mut. *substrobilina* |
| XVI | $F_2$ generation of preceding cross |
| XVII | *Oe. numismatica* mut. *substrobilina* × f. *typica* |
| XVIII | $F_2$ generation of preceding cross |
| XIX | *Oe. pratincola* f. *typica* × *Oe. numismatica* mut. *substrobilina* |
| XX | $F_2$ generation of preceding cross |

| TABLE | |
|---|---|
| XXI | $F_2$ generation of preceding cross |
| XXII | *Oe. numismatica* mut. *substrobilina* × *Oe. pratincola* f. *typica* |
| XXIII | $F_2$ generation of preceding cross |
| XXIV | *Oe. numismatica* f. *typica* × *Oe. pratincola* mut. *strobilina* |
| XXV | $F_2$ and $F_3$ generations of preceding cross |
| XXVI | *Oe. numismatica* f. *typica* × *Oe. pratincola* mut. *simulans* |
| XXVII | $F_2$ generation of preceding cross |
| XXVIII | *Oe. pratincola* mut. *simulans* × *Oe. numismatica* f. *typica* |
| XXIX | $F_2$ generation of preceding cross |
| XXX | *Oe. pratincola* f. *typica* × hyb. *typica* with red buds and viscid pubescence |
| XXXI | $F_2$ and $F_3$ generations of preceding cross |
| XXXII | *Oe. pratincola* hyb. *typica* with red buds and viscid pubescence × f. *typica* |
| XXXIII | $F_2$ generation of preceding cross |
| XXXIV | *Oe. pratincola* hyb. *simulans* with green buds × hyb. *typica* with red buds and viscid pubescence |
| XXXV | *Oe. pratincola* hyb. *simulans* with green buds × f. *typica* |
| XXXVI | *Oe. pratincola* hyb. *typica* with red buds and viscid pubescence × hyb. *simulans* with green buds |
| XXXVII | *Oe. pratincola* f. *typica* × hyb. *simulans* with green buds |
| XXXVIII | Plant of alpha-alpha constitution (see Table XXVIII) × *Oe. pratincola* hyb. *typica* with red buds and viscid pubescence |
| XXXIX | Plant of alpha-alpha constitution (see Table XXVIII) × *Oe. pratincola* f. *typica* |
| XL | *Oe. pratincola* hyb. *typica* with red buds and viscid pubescence × plant of alpha-alpha constitution (see Table XXVIII) |
| XLI | *Oe. pratincola* f. *typica* × plant of alpha-alpha constitution (see Table XXVIII) |
| XLII | *Oe. numismatica* hyb. *typica* × *Oe. pratincola* hyb. *typica* with red buds and viscid pubescence |
| XLIII | *Oe. numismatica* hyb. *typica* × *Oe. pratincola* f. *typica* |
| XLIV | *Oe. pratincola* hyb. *typica* with red buds and viscid pubescence × *Oe. numismatica* hyb. *typica* |
| XLV | *Oe. pratincola* f. *typica* × *Oe. numismatica* hyb. *typica* |
| XLVI | $F_2$ generation of preceding cross |

### *Questionable Points in the Tables*

The twenty-seven crosses recorded in the tables amply support the hypothesis of the constitutions of the forms proposed on page 87. Every point in the tables which fails to support this hypothesis is discussed in the following four paragraphs:

1. A single green-budded individual occurred among 495 hyb. *typica* plants with red buds in the $F_1$ generation of the cross *Oe. pratincola* f. *typica* × mut. *simulans* (see Table II).

Seeds of this plant were grown, and the progeny all had green buds (see Table IV). This single plant is interpreted as either a mutation, or, much more probably, a plant included in this culture by error.

2. Since the $\alpha$ gametes of *Oe. pratincola* f. *typica* and its mutations are all assumed to carry the recessive factor for red bud color, it might be expected that a plant of $\alpha\alpha$ constitution combining any two of these $\alpha$ gametes would show red bud color. However, plants combining the $\alpha$ of f. *typica* with the $\alpha$ of mut. *simulans* (Table II) and the $\alpha$ of mut. *simulans* with $\alpha$ of mut. *nitidissima* (Table XI) have green buds. It is characteristic of all the $\alpha\alpha$ combinations so far observed that they lack red pigment in all parts. Apparently the red factor produces red in all cases only by interaction with factors carried in $\beta$.

3. In several cultures in which red buds should be expected, the buds were recorded as red, but not fully red (see Tables VI, VIII, and XXXI). In these cases the color record was made late in the flowering period of the culture, and, as is explained in the footnote of Table VI, it is only at the height of flowering that the buds show the full amount of red, the coloring being less intense and continuous both early and late in the flowering of a plant.

4. In plants constituted of $\alpha$ of *Oe. numismatica* (which carries the factor for green buds) and $\beta$ of *Oe. pratincola* mut. *simulans* (which carries the factor for red buds), the buds, instead of being completely green, show a very slight touch of red mottling (see Tables XXVI and XXXVIII), indicating that dominance is not quite complete, or that bud color is really determined by multiple factors of which only the one with the most conspicuous effect has been studied here.

The four preceding items form a complete array of all the disturbing elements of the tables which have been found by the writers. The hypothesis in regard to the bud color factors of the forms used in the experiment seems justified by the overwhelming amount of evidence included in Tables II to XLVI inclusive.

*Summary of the Conclusions as to Bud Color*

The crosses may be summarized in brief as showing: (1) matroclinic inheritance of general plant form, the $F_1$ and succeeding generations breeding true to the type of the pistillate parent; (2) a segregation in regard to pubescence which suggests Mendelian behavior; (3) in general a patroclinic inheritance of bud color, which, however, fails in certain cases, suggesting that the forms used in these experiments are not all alike in the factors for bud color which they carry, and leading to the adoption of the constitutions suggested on page 87.

The tables show no case of a cross between two plants with red buds producing plants with green buds. All plants with red buds are homozygous recessives. However, two suitable green-budded plants, both heterozygous, but one carrying the red factor in $\alpha$, the other in $\beta$, have produced plants with red buds. This is brought out in Table XLVII, which briefly summarizes the inheritance of bud color shown by the tables which record the $F_1$ generation of crosses.

*Oe. numismatica* and its mutation *substrobilina,* of all the forms used, *must* have green buds; any of the other forms may have either red or green buds, and the color may be changed at will by suitable crossing. The $\alpha$ which carries the group of factors for the particular combination of characters which comprise *Oe. numismatica,* also carries a dominant factor for green buds.

The factor for red bud color present in the $\beta$ of mut. *simulans* but absent in the $\beta$ of its parent form, *Oe. pratincola,* doubtless came from $\alpha$, which normally carries the factor, by a breaking away from the $\alpha$ group, in a single case, of the chromosome carrying the red bud factor, and its interchange with the corresponding chromosome in a $\beta$ group. This altered $\beta$ united with a normal $\alpha$, thus producing a zygote carrying two factors for red bud color. The acquisition of red buds was of course only part of the change involved in the production of mut. *simulans.*

THE BEARING OF THE RESULTS ON OTHER PROBLEMS

In most of the progenies a small number of mutations occurred. In every case these were, both in kind and number, what might be expected from the self-pollination of the egg parent. There is no evidence here of mutations having been induced by hybridization. A list with brief description of the mutations occurring in the cultures precedes the tables.

There are several instances of individual plants showing a combination of the characteristics of two of the regularly occurring mutations of the species studied, and, though these double mutations have no bearing on the problem in hand, it is thought that they should be recorded in passing. These are listed below, with the numbers of the tables in which they occur:

TABLE
II mut. *simulans fallax*
VI mut. *nitidissima robusta*
X revolute-leaved mut. *simulans*
XI mut. *simulans angustifolia*
XXII mut. *substrobilina fallax*

The tabulations of the crosses between *Oe. pratincola* f. *typica* and *Oe. numismatica* f. *typica* have been omitted, as they add nothing new to the discussion and are more appropriately included in another paper which is being prepared. The reciprocal crosses between these forms have been tested to the fifth filial generation, with the production of only green-budded plants. Moreover, the reciprocal crosses, recorded in this paper, between *Oe. pratincola* f. *typica* and *Oe. numismatica* mut. *substrobilina*, and the cross *Oe. numismatica* f. *typica* by *Oe. pratincola* mut. *strobilina* duplicate the omitted crosses between the typical forms of the two species, since, in regard to the factors for bud color, these mutations and their parent forms are equivalent.

A study of the inheritance of pubescence is being made, and will be discussed in a separate paper. In the tables of the present paper the pubescence characters are merely recorded, and not discussed. It might be said, however, that the results given here are entirely in accord with other records, and are just what would be expected.

The inheritance of another character, the color of the tip of the axis of the inflorescence, is also under investigation, and is recorded here only incidentally. The stem of mut. *nitidissima* is red throughout. The $\alpha$ gamete carries the factor for red stems, except for the tip inch or two of the axis of the inflorescence; the factor for the redness of this part is carried by $\beta$ of mut. *nitidissima*. Thus *Oe. pratincola* mut. *nitidissima* × f. *typica* gives mut. *nitidissima* with green instead of red tips to the branches (see Tables V and VI); and the reciprocal cross, f. *typica* × mut. *nitidissima*, gives f. *typica* (green stems) with red instead of green tips to the branches (see Tables XI, note, and XII). Although the cultures included in Tables V and VI were classified as mut. *nitidissima*, it was recorded that the stems were not as red as is usual in mut. *nitidissima*. It was not recognized at that time that the difference lay almost entirely in the color of the tips. They would now be recorded as "mut. *nitidissima* with green tips."

It has been repeatedly noticed in the forms used in this study and in their allies that the staminate parents of the crosses, i.e., the beta gametes, have an elusive general effect on the inflorescence of the offspring. We can speak definitely of the contribution of red bud color and viscid pubescence by the staminate parent; but this is not the whole of the story. In the cross *Oe. numismatica* × *Oe. pratincola* mut. *simulans* (see Tables XXVI and XXVII, note) the progenies are classified as *Oe. numismatica*, but it is recorded that the inflorescences are more like mut. *simulans* than they should be. In the cross *Oe. numismatica* hyb. *typica* × *Oe. pratincola* hyb. *typica* with red buds (see Table XLII) the progenies again were classed as *Oe. numismatica*, but it was recorded that the inflorescences were rather *pratincola*-like. It is probable that, when the investigations have progressed further, these "likenesses" may be recognized in terms of definite characters; but thus far these slight and not readily defined differences have been neglected in favor of the more readily observed characters such as red and green bud color, and the presence and absence of viscid pubescence.

*Plants of Alpha-alpha Constitution*

Since *Oe. numismatica,* its mutation *substrobilina,* and *Oe. pratincola* mut. *nitidissima* all produce two kinds of functional sperms, $\alpha$ and $\beta$, in crosses where any one of these forms is used as pollen parent we expect twin hybrids, plants of $\alpha\beta$ and of $\alpha\alpha$ constitutions (see Tables XI, XIX, XXVIII). In Table XV, where *Oe. numismatica* is the pistillate parent and its mutation *substrobilina* the staminate parent, and in Table XVII, the reciprocal cross, the $\alpha\alpha$ plants do not occur in the $F_1$ generation. This may be accounted for by the logical supposition that these two forms, derived one from the other, carry the same zygotic lethal, and the $\alpha\alpha$ combination is therefore unviable, as in the self-pollination of *Oe. numismatica.*

We should also expect to find occasional $\alpha\alpha$ plants in any $F_1$ culture, resulting from the rare $\alpha$ sperms which occur among the $\beta$ sperms in most forms (see Tables II and XXX).

However, because a certain gamete functions as an egg when in association with one type of gamete it does not necessarily do so when with another. It might be expected that hybrids carrying $\alpha$ of *Oe. numismatica,* its mutation *substrobilina,* or *Oe. pratincola* mut. *nitidissima* would necessarily produce functioning $\alpha$ sperms, but this is not necessarily true.[1] In the crosses recorded in Tables XLIV and XLV, *numismatica* $\alpha$ is combined with *simulans* $\beta$. In this combination it does not function as a sperm, except very rarely, although it does when with its own *numismatica* $\beta$; $\alpha\alpha$ hybrids are, therefore, practically absent from these cultures.

The pollen parent of the crosses recorded in Tables XL and XLI is of $\alpha\alpha$ constitution, but it is not recorded here which $\alpha$ functioned as the sperm.

An irregularity among the $\alpha\alpha$ plants occurs in Table XXXIX. Here the pistillate parent is *numismatica* $\alpha$ *simulans* $\alpha$. We should therefore expect, when it is fertilized by $\beta$ sperms, twin hybrids, i.e., *Oe. numismatica* and *Oe. pratincola* mut. *simulans,* as in Table XXXVIII. The twenty-five plants of

[1] See the following paper in this volume for a discussion of this matter.

this culture, however, are all mut. *simulans*. No explanation can be offered, but it should be remarked that when there are two types of $\alpha$ eggs there seems generally to be great variation in the proportions of the two.

An unexpected result occurs in Table XXIII, the $F_2$ generation of the cross *Oe. numismatica* mut. *substrobilina* × *Oe. pratincola* f. *typica*. A group of glabrous plants is here referred to as possibly of $\alpha\alpha$ constitution. This constitution is suggested because the plants resemble the general $\alpha\alpha$ type, and because they occur regularly, though in small numbers, in the four cultures of the table. There is, however, apparently no more reason to expect plants of $\alpha\alpha$ constitution in these cultures than in cultures from the self-pollination of mut. *substrobilina* (which produces functional $\alpha$ sperms), since the two combining $\alpha$ gametes must both be the $\alpha$ of mut. *substrobilina*.

With these two cases excepted, the occurrence of the $\alpha\alpha$ plants in the tables is exactly what would be predicted.

### *Plants of Beta-beta Constitution*

Occasional plants of $\beta\beta$ constitution occur in the progenies (see Tables II and IX) though there are no cultures in which a large portion of the plants are of this constitution, since the forms used in these crosses seldom produce functioning $\beta$ eggs.

### *Metaclinic Plants*

Metaclinic plants, those deriving $\alpha$ from the staminate parent and $\beta$ from the pistillate parent, occur in Tables XI and XXX. These plants of course resemble the male instead of the female parent.

Some indication of the frequency with which $\beta$ eggs function in one form, *Oe. pratincola* mut. *simulans*, is given in the cross *Oe. pratincola* mut. *simulans* × mut. *nitidissima* (see Table XI), where of 123 functioning $\alpha$ sperms of mut. *nitidissima* only one united with a $\beta$ egg of mut. *simulans*, the other 122 uniting with $\alpha$ eggs.

### *White and "Lethal" Seedlings*

In Table XII there were recorded three classes of seedlings, occurring in about equal numbers, only one of which survived. The latter class consisted of normal green plants. The second class consisted of white plants which of course died because of lack of chlorophyll. The third class, called "lethal," consisted of perhaps a third of the seedlings, in which the cotyledons failed to expand after germination. The cotyledons remained of the same size as the undeveloped cotyledons within the seed, and it was never possible to keep the plants longer than a few days. A more critical analysis of the cultures would have given a fourth class, consisting of white "lethals," some of which were counted in with the white plants, and others doubtless included with the "lethals." The factors concerned with "white" and "lethal" are being studied and are discussed at greater length in the paper immediately following in this volume. It is assumed that they have no necessary bearing on the subject in hand.

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## EXPLANATIONS APPLYING TO ALL THE TABLES

In Table I, all plants not otherwise designated are f. *typica*. The following abbreviations are used to designate some of the mutations:

n = *Oe. pratincola* mut. *nitidissima*
s = *Oe. pratincola* mut. *simulans*
str = *Oe. pratincola* mut. *strobilina*
substr = *Oe. numismatica* mut. *substrobilina*

In the table headings, a plant is designated as *typica* if it is of the typical form of the species. If the plant is not of hybrid origin, it is designated f. *typica*; if of hybrid origin, hyb. *typica*. If it is of hybrid origin and differs from the typical form in any visible characteristic, it is called hyb. *typica*, and the characteristic in which it differs is specified; if it is simply called hyb. *typica* it is indistinguishable from f. *typica* in appearance. The mutations are treated in the same way as the species.

The placing of descriptions of plants in parentheses, as "*Oe. numismatica* hyb. *typica* (green buds, viscid pubescence)" indicates that these characteristics are typical of the form; the ab-

sence of parentheses indicates that the plant differs from type in the characteristics mentioned, as "*Oe. pratincola* hyb. *typica* with red buds and viscid pubescence."

In all tables the number in the column headed "Key number" refers to the corresponding number in Table I. The number in the column headed "Parent plant" is the number of the individual plant, in the progeny resulting from the cross or self-pollination indicated under "Key number," which was used as the parent of the culture.

In most cases seeds from several capsules were sown together.

Data in the columns following "Plants saved" are from field notes taken in July, August and September.

The following is a list of the forms occurring in the cultures considered in this paper (exclusive of the forms used as parents, which are listed and described briefly on page 84) with citations of published references:

Mut. *angustifolia* (Bartlett, 1915 *c*, p. 438), a not uncommon narrow-leaved mutation of *Oe. pratincola.*

Mut. *denticulata*, a mutation attributed to *Oe. numismatica*, which has arisen frequently in the crosses between *Oe. numismatica* and *Oe. pratincola*, and seems to be a form corresponding to *Oe. pratincola* mut. *fallax.*

Mut. *ericacea*, a small, rigid, dark-leaved form, one of the most frequently occurring mutations of *Oe. pratincola.*

Mut. *fallax*, one of the most frequently occurring mutations of *Oe. pratincola*, a form resembling mut. *nummularia*, especially in the seedling stages, but giving in every generation a progeny which is composed of mut. *fallax* and f. *typica.*

Mut. *latifolia*, a type with a weak stem and relatively crowded broad leaves, perhaps corresponding to *Oe. Lamarckiana* mut. *lata*, and showing the *lata* type of inheritance.

Mut. *nummularia* (Bartlett 1915 *a*, p. 97), a true-breeding mutation of *Oe. pratincola.*

Mut. *robusta*, a heavy-foliaged, stiff-stemmed mutation showing the *lata* type of inheritance.

Gray plants, of $\beta\beta$ constitution (introduction and text of this paper).

Plants of $\alpha\alpha$ constitution (introduction and text of this paper).

Revolute-leaved forms (Bartlett, 1915 *c*; Cobb and Bartlett, 1919; Cobb, 1921).

## TABLE I

RECORD OF THE PARENTAGE OF ALL THE PROGENIES RECORDED IN THE FOLLOWING TABLES, WITH KEY NUMBERS

All plants designated only by number are f. *typica* of *Oe. pratincola, Oe. numismatica,* or *Oe. Reynoldsii,* as the case may be; n stands for mut. *nitidissima,* s for mut. *simulans,* str for mut. *strobilina,* and substr for mut. *substrobilina.*

1. Oe. pratincola strain E – 43 – 72 – 5 – 6 – 8
2. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 25 s – 34 s
3. Oe. pratincola strain C – 52 – 6 – 25 – 1 – 43
4. Oe. pratincola strain C – (22 – 7 – 40 × 52 – 2 gynocrates – 13 gynocrates) – 95 – 50
5. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 25 s – 33 s
6. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s
7. Oe. pratincola strain C – 72 – 40 – 126 – 43 – 89
8. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 3 s – 1 s
9. Oe. pratincola strain C – 52 – 6 – 25 – 1 – 41
10. Oe. pratincola strain E – 5 – 208 angustifolia – 1 n – 34 n – 36 n
11. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s
12. Oe. pratincola strain E – 5 – 208 angustifolia – 1 n – 182 n – 21 n –8 n
13. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s – 9 s – 4 s
14. Oe. Reynoldsii – (89 – 53 – 1 × 89 – 3 – 13 – 134 debilis) – 56
15. Oe. pratincola strain E – 43 – 89 – 5 – 19 – 11 – 9 – 8
16. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 3 s – 9 s
17. Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 3 s – 20 s
18. Oe. pratincola strain E – 5 – 208 angustifolia – 1 n – 34 n – 36 n
19. Oe. pratincola strain C – 22 – 7 – 40 – 5 – 9 – 2 – 7
20. Oe. pratincola strain C – 90 × Oe. numismatica – 8 } – 1 mutation × Oe. numismatica – 1 – 11 } – 71 denticulata × Oe. numismatica – 1 – 11 – 3 } – 38 substr – 2 substr – 3 substr – 31 substr – 1 substr
21. Oe. numismatica – 1 – 11 – 24 – 28 – 45 – 34 – 9 – 25
22. Oe. pratincola strain E – 36 latifolia – 43 str – 2 str – 20 str – 37 str – 17 str
23. Oe. pratincola strain C – 52 – 6 – 25 – 1 – 43 – 2 × Oe. pratincola strain C – 22 – 7 – 40 × Oe. pratincola strain C – 52 – 2 gynocrates – 13 gynocrates } – 95 – 50 × Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 25 s – 33 s } – 30 pratincola with red buds

**24.** Reciprocal of 23

**25.** Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s – 9 s – 4 s – 19 s
×
Oe. numismatica – 1 – 11 – 24 – 28 – 45 – 34 – 9 – 25 – 1 } – 12 simulans with green buds

**26.** Oe. pratincola strain C – 52 – 6 – 25 – 1 – 41
×
Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 25 s – 34 s } –
1 – 7 – 3 – 12 hyb. typica (red buds)

**27.** Oe. pratincola strain E – 43 – 74 – 41 – 45 – 2 – 25 – 6 – 7

**28.** Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s – 9 s – 4 s – 19 s
×
Oe. numismatica – 1 – 11 – 24 – 28 – 45 – 34 – 9 – 25 – 1 } – 16 alpha-alpha hybrid

**29.** Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s – 9 s – 4 s – 19 s
×
Oe. numismatica – 1 – 11 – 24 – 28 – 45 – 34 – 9 – 25 – 1 } – 13 alpha-alpha hybrid

**30.** Oe. numismatica – 1 – 11 – 24 – 28 – 45 – 34 – 9 – 25 – 1
×
Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s – 9 s – 4 s – 19 s } – 32 numismatica

**31.** Oe. numismatica – 1 – 11 – 24 – 28 – 45 – 34 – 9 – 25 – 1
×
Oe. pratincola strain C – 22 – (15 nitida × 10) – 1 s – 24 s – 2 s – 29 s – 9 s – 4 s – 19 s } – 37 numismatica

**32.** Oe. pratincola strain E – 43 – 89 – 5 – 19 – 11 – 9 – 9 – 8 – 25

## TABLE II

Analysis of the $F_1$ generation of the following cross: *Oe. pratincola* f. *typica* (green buds, without viscid pubescence) × *Oe. pratincola* mut. *simulans* (red buds, viscid pubescence)

Constitutions: $\alpha$ ♀ red; $\beta$♂ green × $\alpha$ ♀ red; $\beta$♂ red → $\alpha$ red $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 1 × 2-1 | 342 | 282 | 75 | 0 | 0 | 65 | 0 | 10 |
| 3-2 × 2-1 | 383 | 351 | 100 | 0 | 0 | 99 | 0 | 1 |
| 4 × 5 | 1,407+ | 509 | 216 | 1 | 0 | 204 | 0 | 11 |
| 3 × 6 | 305 | 4 | 4 | 0 | 0 | 3 | 0 | 1 |
| 7 × 8 | 27 | 7 | 7 | 0 | 0 | 5 | 0 | 0 |
| 9 × 2 | 403 | 121 | 121 | 0 | 0 | 119 | 0 | 2 |
| Total | 2,867+ | 1,274 | 523 | 1 | 0 | 495 | 0 | 25 |

In general the progenies consist of *Oe. pratincola*, with red instead of green buds (except in one plant) and with viscid bud pubescence. The following twenty-five plants are mutational or hybrid types:

14 heavy gray plants, interpreted as of $\beta\beta$ constitution;

6 slender plants, interpreted as of $\alpha\alpha$ constitution;

2 or 3 mut. *nummularia*, a mutation regularly produced by *Oe. pratincola*;

1 mut. *ericacea*, a mutation regularly produced by *Oe. pratincola*;

1 mut. *fallax*, with the pubescence of mut. *simulans*. (Mut. *fallax* is regularly given by *Oe. pratincola*.)

For published references to these forms, and brief characterizations, see page 97.

## TABLE III

ANALYSIS OF THE $F_2$ AND FOLLOWING GENERATIONS RESULTING FROM THE SELF-POLLINATION OF *Oe. pratincola* hyb. *typica* PLANTS WITH RED BUDS AND VISCID PUBESCENCE, CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE II

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| $F_2$ GENERATION | | | | | | | | | |
| 1 × 2-1 | 33 | ca. 950 | 539 | 100 | 0 | 0 | 97 | 3 | 0 |
| 1 × 2-1 | 15 | ca. 1,000 | 512 | 100 | 0 | 0 | 95 | 5 | 0 |
| 1 × 2-1 | 38 | | 454 | 100 | 0 | 0 | 96 | 0 | 4 |
| 1 × 2-1 | 21 | ca. 1,000 | 514 | 100 | 0 | 0 | 94 | 3 | 3 |
| 4 × 5 | 1 | ca. 1,350 | 218 | 25 | 0 | 0 | 21 | 3 | 1 |
| 4 × 5 | 3 | ca. 1,050 | 435 | 25 | 0 | 0 | 24 | 1 | 0 |
| 4 × 5 | 22 | ca. 1,700 | 714 | 25 | 0 | 0 | 25 | 0 | 0 |
| 3 × 6 | 3 | ca. 950 | 405 | 25 | 0 | 0 | 25 | 0 | 0 |
| 3 × 6 | 4 | ca. 1,200 | 578 | 25 | 0 | 0 | 22 | 3 | 0 |
| 9 × 2 | 2 | ca. 1,750 | 445 | 25 | 0 | 0 | 25 | 0 | 0 |
| 9 × 2 | 7 | ca. 1,900 | 627 | 25 | 0 | 0 | 24 | 1 | 0 |
| 9 × 2 | 1 | ca. 1,600 | 435 | 25 | 0 | 0 | 23 | 1 | 1 |
| 7 × 8 | 6 | ca. 1,950 | 1,235 | 25 | 0 | 0 | 23 | 2 | 0 |
| 7 × 8 | 7 | ca. 1,550 | 585 | 25 | 0 | 0 | 24 | 1 | 0 |
| 7 × 8 | 1 | ca. 1,600 | 520 | 25 | 0 | 0 | 23 | 1 | 1 |
| TOTAL | | ca. 19,550 | 8,216 | 675 | 0 | 0 | 641 | 24 | 10 |
| $F_3$ GENERATION | | | | | | | | | |
| 1 × 2-1 | 21-3 | 480 | 53 | 25 | 0 | 0 | 23 | 2 | 0 |
| 9 × 2 | 1-7 | ca. 1,150 | 853 | 25 | 0 | 0 | 24 | 1 | 0 |
| 3 × 6 | 3-6 | ca. 600 | 431 | 25 | 0 | 0 | 24 | 1 | 0 |
| 3 × 6 | 3-9 | ca. 850 | 433 | 25 | 0 | 0 | 25 | 0 | 0 |
| TOTAL | | ca. 3,080 | 1,770 | 100 | 0 | 0 | 96 | 4 | 0 |

TABLE III (*continued*)

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| $F_4$ Generation | | | | | | | | | |
| 9 × 2 | 1-7-3 | 678 | 45 | 25 | 0 | 0 | 25 | 1 | 0 |
| $F_5$ Generation | | | | | | | | | |
| 9 × 2 | 1-7-3-12 | | ca. 200 | 10 | 0 | 0 | 10 | 0 | 0 |
| $F_6$ Generation | | | | | | | | | |
| 9 × 2 | 1-7-3-12-2 | | 40 | 25 | 0 | 0 | 25* | | 0 |
| $F_7$ Generation | | | | | | | | | |
| 9 × 2 | 1-7-3-12-2 -11 | | ca. 1225 | 25 | 0 | 0 | 22 | 3 | 0 |

The red bud characteristic breeds true. The splitting in the $F_2$ and following generations into plants with viscid pubescence and plants without it suggests Mendelian behavior. A study of this segregation is in progress. Aside from pubescence, the tested plants breed true, giving only the usual small number of mutations, as follows:

3 mut. *robusta*-like plants. Mut. *robusta* is regularly produced by *Oe. pratincola*;

1 dwarf mutation;

6 unclassified mutations.

For published references to these forms, and brief characterizations, see page 97.

* In this one culture it was not definitely recorded that the individuals were all viscid-pubescent.

## TABLE IV

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF THE ONLY PLANT WITH GREEN BUDS IN THE $F_1$ GENERATION RECORDED IN TABLE II

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 4 × 5 | 73 | ca. 1,500 | 1,157 | 25 | 25 | 0 | 0 | 0 | 0 |

The parent of this progeny, the only plant with green buds among 412 $F_1$ plants from six similar crosses, must be interpreted either as a mutation, or as a plant included in this culture by error.

## TABLE V

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *nitidissima* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ red → $\alpha$ red $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | Mut. *nitidissima* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 10 × 11 | 376 | 94 | 50 | 0 | 0 | 50 | 0 | 0 |
| 12 × 13 | 485 | 44 | 44 | 0 | 0 | 42 | 0 | 0 |
| TOTAL | 861 | 138 | 94 | 0 | 0 | 92 | 0 | 0 |

The progenies consist entirely of *Oe. pratincola* mut. *nitidissima* with red instead of green buds. It was recorded, however, that the stems were not so completely red in these cultures and in those of Table VI as in mut. *nitidissima*.

## TABLE VI

Analysis of the $F_2$ and following generations resulting from the self-pollination of plants of *Oe. pratincola* hyb. *nitidissima* with red buds chosen at random from the $F_1$ generation recorded in Table V

| Key number | Parent plant | Germinations | Plants saved | *Oe. nitidissima* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| $F_2$ Generation | | | | | | | | |
| 12 × 13 | 3 | 120 | 25 | 0 | 0 | 24 | 0 | 1 |
| 12 × 13 | 5 | ca. 150 | 50 | 0 | 0 | 49 | 0 | 1 |
| Total | | ca. 270 | 75 | 0 | 0 | 73 | 0 | 2 |
| $F_3$ Generation | | | | | | | | |
| 12 × 13 | 5-36 | 5 | 5 | 0 | 0 | 3 | 0 | 2 |
| $F_4$ Generation | | | | | | | | |
| 12 × 13 | 5-36-5 | 40 | 25 | 0 | 0 | 25 | 0 | 0 |

The bud color of these progenies was recorded as red, but not completely so. It is generally only at the height of the season that buds show their full redness; both early and late in the flowering period the red is somewhat mottled rather than continuous. It is known that the color may be somewhat modified also by genetic factors other than those more largely responsible for bud color.

The tested plants of the $F_1$ and following generations breed true, producing only 4 mutations: 1 unclassified dwarf, 1 mut. *robusta*-like plant, and, in the $F_3$ generation, 2 plants of mut. *robusta* with the red stem and dark green leaf color of mut. *nitidissima*.

## TABLE VII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. Reynoldsii* f. *typica* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ red → $\alpha$ red $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | *Oe. Reynoldsii* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 14-21 × 5 | 806 | 216 | 200 | 0 | 0 | 197 | 0 | 3 |
| 14-23 × 5 | 559 | 32 | 32 | 0 | 0 | 32 | 0 | 0 |
| 14-59 × 5 | 572 | 50 | 50 | 0 | 0 | 50 | 0 | 0 |
| TOTAL | 1,937 | 298 | 282 | 0 | 0 | 279 | 0 | 3 |

The progenies consist entirely of *Oe. Reynoldsii* with red instead of green buds. The resemblance of *Oe. pratincola* mut. *simulans* to *Oe. Reynoldsii*, on account of which it was named, is so complete, with the exception of the bud color, and the differences are so slight and so general, that it was quite a matter of indifference whether these plants were called *Oe. Reynoldsii* or *Oe. pratincola* mut. *simulans*. They were called *Oe. Reynoldsii* because their characteristic $\alpha$ was assumed to have come from this species.

Only 3 mutations, all unclassified, occurred in these cultures.

## TABLE VIII

ANALYSIS OF THE $F_2$ AND $F_3$ GENERATIONS RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. Reynoldsii* hyb. *typica* WITH RED BUDS, CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE VII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | *Oe. Reynoldsii* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| $F_2$ GENERATION | | | | | | | | | |
| 14-21 × 5 | 12 | ca.1,350 | 168 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-21 × 5 | 1 | ca.1,750 | 552 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-59 × 5 | 42 | ca.1,000 | 286 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-59 × 5 | 25 | ca. 900 | 270 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-59 × 5 | 22 | ca.1,700 | 277 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-59 × 5 | 12 | ca.1,100 | 262 | 25 | 0 | 0 | 25 | 0 | 0 |
| TOTAL | | ca.7,800 | 1,815 | 150 | 0 | 0 | 150 | 0 | 0 |
| $F_3$ GENERATION | | | | | | | | | |
| 14-59 × 5 | 12-13 | ca. 625 | 78 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-59 × 5 | 12-14 | ca. 850 | 179 | 25 | 0 | 0 | 25 | 0 | 0 |
| 14-59 × 5 | 22-22 | ca. 750 | 359 | 25 | 0 | 0 | 25 | 0 | 0 |
| TOTAL | | ca.2,225 | 616 | 75 | 0 | 0 | 75 | 0 | 0 |

The tested plants of the $F_2$ and $F_3$ generations breed true. In the $F_3$ generation the buds were recorded as "mottled with red." See note to Table VI.

## TABLE IX

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE) × *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ red × $\alpha$ ♀ red; $\beta$ ♂ green → $\alpha$ red $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 2–1 × 1 | 475 | 376 | 100 | 98 | 0 | 0 | 0 | 2 |
| 13 × 15 | 141 | 65 | 65 | 65 | 0 | 0 | 0 | 0 |
| 8 × 7 | 331 | 189 | 160 | 160 | 0 | 0 | 0 | 0 |
| 16 × 3 | 232 | 40 | 40 | 39 | 0 | 0 | 0 | 0 |
| 5 × 4 | 831 | 212 | 88 | 88 | 0 | 0 | 0 | 0 |
| 17 × 3 | 343 | 3 | 3 | 3 | 0 | 0 | 0 | 0 |
| 6 × 3 | 155 | 20 | 20 | 20 | 0 | 0 | 0 | 0 |
| 2-1 × 3-2 | ca. 100 | 32 | 32 | 32 | 0 | 0 | 0 | 0 |
| TOTAL | ca.2,608 | 937 | 508 | 505 | 0 | 0 | 0 | 2 |

The progenies consist entirely of *Oe. pratincola* mut. *simulans* with green instead of red buds, with the exception of two plants of the heavy gray type which has been interpreted as of $\beta\beta$ constitution.

## TABLE X

ANALYSIS OF THE $F_2$ AND FOLLOWING GENERATIONS RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE IX

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescense | Viscid pubescence | Without viscid pubescence | |
| $F_2$ GENERATION | | | | | | | | | |
| 13 × 15 | 10 | | 55 | 50 | 46 | 2 | 0 | 0 | 2 |
| 5 × 4 | 19 | ca.1,050 | 211 | 25 | 22 | 2 | 0 | 0 | 1 |
| 5 × 4 | 21 | ca.1,100 | 322 | 25 | 23 | 1 | 0 | 0 | 1 |
| 5 × 4 | 13 | ca. 800 | 40 | 25 | 24 | 0 | 0 | 0 | 1 |
| 8 × 7 | 73 | ca.1,600 | 531 | 100 | 94 | 5 | 0 | 0 | 1 |
| 8 × 7 | 17 | ca. 850 | 294 | 25 | 23 | 1 | 0 | 0 | 1 |
| 8 × 7 | 96 | ca.1,050 | 495 | 50 | 46 | 2 | 0 | 0 | 2 |
| 17 × 3 | 1 | ca.1,400 | 365 | 50 | 43 | 5 | 0 | 0 | 1 |
| 6 × 3 | 5 | ca.1,250 | 239 | 50 | 46 | 4 | 0 | 0 | 0 |
| TOTAL | | ca.9,100 | 2,552 | 400 | 367 | 22 | 0 | 0 | 10 |
| $F_3$ GENERATION | | | | | | | | | |
| 5 × 4 | 19-14 | ca. 750 | 359 | 25 | 22 | 3 | 0 | 0 | 0 |
| 17 × 3 | 1-20 | ca.1,000 | 655 | 25 | 25 | 0 | 0 | 0 | 0 |
| 6 × 3 | 5-2 | ca. 650 | 474 | 25 | 21 | 3 | 0 | 0 | 0 |
| TOTAL | | ca.2,400 | 1,488 | 75 | 68 | 6 | 0 | 0 | 0 |
| $F_4$ GENERATION | | | | | | | | | |
| 6 × 3 | 5-2-11 | 412 | 82 | 25 | 24 | 1 | 0 | 0 | 0 |

The tested plants breed true to the $F_1$ type, except for the usual segregation in respect to pubescence and the production of the expected small number of mutations, as follows:

8 unclassified mutations;

2 mut. *simulans* with the revolute leaf character introduced through strain E of *Oe. pratincola*.

## TABLE XI

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE) × *Oe. pratincola* mut. *nitidissima* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ red × $\alpha$ ♀ red; $\alpha$ ♂ red and $\beta$ ♂ green → $\alpha$ ♀ red $\alpha$ ♂ red and $\alpha$ ♀ red $\beta$ ♂ green

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* * | | | | Plants of $\alpha\alpha$ constitution | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | | |
| 11 × 18 | 525 | 346 | 100 | 34 | 0 | 0 | 0 | 64 | 1 |
| 13 × 12 | 444 | 136 | 100 | 38 | 0 | 0 | 0 | 59 | 1 |
| TOTAL | 969 | 482 | 200 | 72 | 0 | 0 | 0 | 123 | 2 |

The progenies consist of two types, because *Oe. pratincola* mut. *nitidissima* produces two types of functioning sperms, $\alpha$ and $\beta$. The 72 plants like *Oe. pratincola* mut. *simulans*, but with green buds, are of constitution homologous to the other $F_1$ progenies of this paper, i.e., they are of $\alpha\beta$ constitution. The other group, of 123 plants, is interpreted as having an $\alpha\alpha$ constitution. The latter group did not come into blossom until late in September, and no seed ripened. Unfortunately, no record of bud color was made.

Of the two plants which fall into neither of these groups, one is a counterpart of *Oe. pratincola* mut. *angustifolia*, but with the general characteristics of mut. *simulans*, i.e., it is mut. *simulans angustifolia*. The other is *Oe. pratincola* mut. *nitidissima*, with buds red, but not completely so; i.e., it is a metaclinic plant, exactly like the $F_1$ plants of the reciprocal cross, and is the result of the union of a $\beta$ egg and an $\alpha$ sperm. This culture gives some indication of the frequency with which $\beta$ eggs function in *Oe. pratincola* mut. *simulans*, since of the 124 $\alpha$ sperms of mut. *nitidissima* demonstrated in this table, only one united with a $\beta$ egg, the other 123 uniting with the usual $\alpha$ egg.

* It has been mentioned in the discussion of $\alpha$ and $\beta$ gametes that the $\beta$ gametes of *Oe. pratincola* mut. *nitidissima* carry a factor which causes the growing tip of the axes of all inflorescences to be bright red, for an inch or two, instead of green. The plants of this group show this characteristic.

## TABLE XII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XI

| Key number | Parent plant | Germinations | Plants saved | Mut. *simulans* * | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 13 × 12 | 8 | ca. 264 | 50 | 50 | 0 | 0 | 0 | 0 |
| 13 × 12 | 18 | ca. 604 | 25 | 25 | 0 | 0 | 0 | 0 |
| TOTAL | | ca. 868 | 75 | 75 | 0 | 0 | 0 | 0 |

With regard to the characters under consideration, the $F_2$ generation consists entirely of plants like those of the $F_1$ generation.

For a discussion of the three types of seedlings occurring in these cultures, see page 95.

* See footnote to Table XI

## TABLE XIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE) × *Oe. Reynoldsii* f. *typica* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$♂ red × $\alpha$ ♀ red; $\beta$♂ green → $\alpha$ red $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 5 × 14-23 | 496 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| 5 × 14-21 | 128 | 45 | 43 | 43 | 0 | 0 | 0 | 0 |
| TOTAL | 624 | 47 | 45 | 45 | 0 | 0 | 0 | 0 |

The progenies consist entirely of *Oe. pratincola* mut. *simulans* with green instead of red buds. (See note at foot of Table VII.)

## TABLE XIV

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XIII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 5 × 14-21 | 39 | ca.1,150 | 511 | 50 | 50 | 0 | 0 | 0 | 0 |
| 5 × 14-21 | 1 | ca.1,200 | 352 | 50 | 49 | 0 | 0 | 0 | 1 |
| TOTAL | | ca.2,350 | 863 | 100 | 99 | 0 | 0 | 0 | 1 |

The $F_2$ generation is exactly like the $F_1$ generation, with the exception of 1 unclassified mutation.

## TABLE XV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* f. *typica* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. numismatica* mut. *substrobilina* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ green; $\alpha$♂ green and $\beta$♂ green × $\alpha$ ♀ green; $\alpha$♂ green and $\beta$♂ green → $\alpha$ green $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 21 × 20 | 437 | 95 | 95 | 95 | 0 | 0 | 0 | 0 |

The progeny consists entirely of typical plants of *Oe. numismatica*. The $\alpha\alpha$ combination does not live. Apparently $\alpha$ of mut. *substrobilina* carries the zygotic lethal factor of its parent form, *Oe. numismatica*.

## TABLE XVI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. numismatica* hyb. *typica* CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XV

| Key number | Parent plant | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 21 × 20 | 3 | ca. 100 | 25 | 25 | 0 | 0 | 0 | 0 |
| 21 × 20 | 7 | ca. 450 | 50 | 50 | 0 | 0 | 0 | 0 |
| 21 × 20 | 14 | ca. 125 | 25 | 25 | 0 | 0 | 0 | 0 |
| TOTAL | | ca. 675 | 100 | 100 | 0 | 0 | 0 | 0 |

The $F_2$ generation is exactly like the $F_1$.

## TABLE XVII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* mut. *substrobilina* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. numismatica* f. *typica* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ green × $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ green → $\alpha$ green $\beta$ green (and $\alpha$ green $\alpha$ green?)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *substrobilina* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 20 × 21 | 55 | 37 | 37 | 12 | 0 | 0 | 0 | 0 |

The plants which grew to maturity were mut. *substrobilina*. It is probable that 25 plants which died young were of $\alpha\alpha$ constitution.

## TABLE XVIII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. numismatica* hyb. *substrobilina* CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XVII

| Key number | Parent plant | Germinations | Plants saved | Mut. *substrobilina* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 20 × 21 | 4 | ca. 75 | 25 | 25 | 0 | 0 | 0 | 0 |
| 20 × 21 | 25 | 55 | 50 | 50 | 0 | 0 | 0 | 0 |
| 20 × 21 | 29 | 12 | 12 | 12 | 0 | 0 | 0 | 0 |
| TOTAL | | ca. 142 | 87 | 87 | 0 | 0 | 0 | 0 |

The progenies consist entirely of mut. *substrobilina*.

## TABLE XIX

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS; *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE) × *Oe. numismatica* mut. *substrobilina* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ green × $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ green → $\alpha$ red $\alpha$ green and $\alpha$ red $\beta$ green

| Key number | Seeds planted | Germinations | Plants Saved | *Oe. pratincola* | | | | Plants of $\alpha\alpha$ constitution |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 19-7 × 20 | 455 | 164 | 150 | 138 | 0 | 0 | 0 | 12 |

The progeny consists of *Oe. pratincola* with viscid pubescence, with the exception of 12 plants of the type interpreted as of $\alpha\alpha$ constitution.

## TABLE XX

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. pratincola* hyb. *typica* WITH VISCID PUBESCENCE CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XIX

| Key number | Parent plant | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 19-7 × 20 | 119 | ca. 525 | 25 | 24 | 1 | 0 | 0 | 0 |
| 19-7 × 20 | 99 | ca. 100 | 25 | 24 | 1 | 0 | 0 | 0 |
| 19-7 × 20 | 134 | ca. 225 | 25 | 23 | 2 | 0 | 0 | 0 |
| TOTAL | | ca. 850 | 75 | 71 | 4 | 0 | 0 | 0 |

The progenies consist of *Oe. pratincola*, 71 of the plants with viscid pubescence and 4 without.

## TABLE XXI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS CHOSEN AT RANDOM FROM THE SECOND HYBRID TYPE (*aa* CONSTITUTION) OF THE $F_1$ GENERATION RECORDED IN TABLE XIX

| Key number | Parent plant | Germinations | Plants saved | Hybrid type of *aa* constitution | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 19-7 × 20 | 109 | ca. 275 | 25 | 24 | 1 | 0 | 0 | 0 |
| 19-7 × 20 | 107 | ca. 500 | 100 | 92 | 7 | 0 | 0 | 1 |
| 19-7 × 20 | 101 | ca. 225 | 25 | 24 | 1 | 0 | 0 | 0 |
| TOTAL | | ca. 1,000 | 150 | 140 | 9 | 0 | 0 | 1 |

With the exception of one unclassified mutation, this hybrid type breeds true. The usual segregation with regard to pubescence occurs, 140 plants having viscid pubescence, the other 9 being without it.

## TABLE XXII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* mut. *substrobilina* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ green → $\alpha$ green $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | Mut. *substrobilina* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 20 × 19-7 | 78 | 43 | 43 | 41 | 0 | 0 | 0 | 2 |

The culture consists of mut. *substrobilina* and 2 mutations, one of them combining the characteristics of mut. *substrobilina* and of mut. *fallax*, the other a glabrous form of mut. *substrobilina*.

## TABLE XXIII

Analysis of the $F_2$ generation resulting from the self-pollination of plants of hyb. *substrobilina* chosen at random from the $F_1$ generation recorded in Table XXII

| Key number | Parent plant | Germinations | Plants saved | Mut. *substrobilina* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 20 × 19-7 | 2 | ca. 125 | 25 | 21 | 1 | 0 | 0 | 3 |
| 20 × 19-7 | 5 | ca. 125 | 25 | 15 | 6 | 0 | 0 | 4 |
| 20 × 19-7 | 9 | ca. 100 | 25 | 20 | 0 | 0 | 0 | 5 |
| 20 × 19-7 | 3 | ca. 200 | 100 | 87* | | 0 | 0 | 13 |
| Total | | ca. 550 | 175 | 143 − | 7 + | 0 | 0 | 25 |

The four cultures consist of 151 plants of mut. *substrobilina*, showing the usual segregation in regard to pubescence, and 25 other plants, of the following types: 17 glabrous plants, possibly of *aa* constitution, 6 resembling mut. *ericacea*, 1 mut. *latifolia*, and 1 mut. *denticulata*.

* This class may have consisted entirely of viscid-pubescent plants, but the field record does not specifically indicate the absence of the type without viscid pubescence.

## TABLE XXIV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* f. *typica* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. pratincola* mut. *strobilina* (GREEN BUDS, WITHOUT VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ green → $\alpha$ green $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 21 × 22 | 424 | 387 | 50 | 50 | 0 | 0 | 0 | 0 |

The progeny consists entirely of *Oe. numismatica* f. *typica*.

## TABLE XXV

Analysis of the $F_2$ and $F_3$ generations resulting from the self-pollination of plants of *Oe. numismatica* hyb. *typica* chosen at random from the $F_1$ generation recorded in Table XXIV

| Key number | Parent plant | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| $F_2$ Generation | | | | | | | | |
| 21 × 22 | 16 | ca. 300 | 100 | 92 | 6 | 0 | 0 | 2 |
| 21 × 22 | 8 | ca. 225 | 25 | 24 | 1 | 0 | 0 | 0 |
| 21 × 22 | 20 | ca. 85 | 25 | 22 | 2 | 0 | 0 | 1 |
| Total | | ca. 610 | 150 | 138 | 9 | 0 | 0 | 3 |
| $F_3$ Generation | | | | | | | | |
| 21 × 22 | 20 – 14 | ca. 125 | 25 | 22 | 0 | 0 | 0 | 3 |

The progenies of the $F_2$ generation consist of 147 plants of *Oe. numismatica*, 138 of them with viscid pubescence and 9 without, and 3 mutations, 2 of them mut. *denticulata*, and 1 of a heavy gray type.

The single $F_3$ culture of 25 plants consists of *Oe. numismatica* and 3 plants of mut. *denticulata*.

## TABLE XXVI

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* f. *typica* (GREEN BUDS, VISCID PUBESCENCE) × *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ red → $\alpha$ green $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 21-1 × 13-19 | ca. 950 | 406 | 125 | 125 | 0 | 0 | 0 | 0 |

The progeny consists entirely of *Oe. numismatica* with buds classed as green, but showing a touch of red, indicating that dominance is not quite complete.

## TABLE XXVII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. numismatica* hyb. *typica* CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXVI

| Key number | Parent plant | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 21-1 × 13-19 | 32 | ca. 625 | 25 | 25 | 0 | 0 | 0 | 0 |
| 21-1 × 13-19 | 24 | ca. 550 | 50 | 50 | 0 | 0 | 0 | 0 |
| TOTAL | | ca. 1,175 | 75 | 75 | 0 | 0 | 0 | 0 |

The progenies were classified as *Oe. numismatica*. It was noted, however, that the form of the inflorescence resembled that of *Oe. pratincola* mut. *simulans* more than is typical of *Oe. numismatica*.

## TABLE XXVIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS, VISCID PUBESCENCE) × *Oe. numismatica* f. *typica* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$♂ red × $\alpha$ ♀ green; $\alpha$♂ green and $\beta$♂ green → $\alpha$ red $\alpha$ green and $\alpha$ red $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Plants of $\alpha\alpha$ constitution |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 13-19 × 21-1 | ca. 800 | 111 | 75 | 34 | 0 | 0 | 0 | 40 |

The progeny consists of two types: mut. *simulans* with green buds, and a green-budded form with some of the characteristics of mut. *simulans*, but in addition the general character of the type interpreted as of $\alpha\alpha$ constitution.

## TABLE XXIX

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF PLANTS OF *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS, CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXVIII

| Key number | Parent plant | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 13-19 × 21-1 | 25 | ca. 660* | 25 | 25 | 0 | 0 | 0 | 0 |
| 13-19 × 21-1 | 12 | ca. 725 | 25 | 25 | 0 | 0 | 0 | 0 |
| TOTAL | | ca. 1,385 | 50 | 50 | 0 | 0 | 0 | 0 |

The progenies consist entirely of *Oe. pratincola* mut. *simulans* with green buds.

* Thirty-five of these seedlings lacked chlorophyll. See discussion on page 95.

## TABLÆ XXX

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE) × *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (OF THE $F_1$ GENERATION OF THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ red → $\alpha$ red $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 23 | 723 | 584 | 50 | 1 | 1 | 37 | 6 | 2 |

With the exception of 2 plants of mut. *ericacea* with red buds, and 1 unclassified mutation with red buds, the progeny consists of *Oe. pratincola*, 43 of them with red buds and two with green. Of the two green-budded plants, one may be interpreted as a metaclinic plant, of $\beta$ green $\alpha$ red constitution; the other, a dwarf plant, was probably of $\alpha\alpha$ constitution. The usual segregation in regard to pubescence occurs.

## TABLE XXXI

ANALYSIS OF THE $F_2$ AND $F_3$ GENERATIONS RESULTING FROM THE SELF-POLLINATION OF 3 PLANTS OF *Oe. pratincola* hyb. *typica* WITH RED BUDS, 2 OF THEM WITH VISCID PUBESCENCE AND 1 WITHOUT, CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXX

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| $F_2$ GENERATION | | | | | | | | | |
| 23 | 12 | ca. 650 | 500 | 25 | 0 | 0 | 0 | 25 | 0 |
| 23 | 30 | ca. 900 | 590 | 25 | 0 | 0 | 25 | 0 | 0 |
| 23 | 1 | ca. 800 | 653 | 25 | 0 | 0 | 24 | 0 | 0 |
| TOTAL from viscid parents | | ca.1,700 | 1,243 | 50 | 0 | 0 | 49 | 0 | 0 |
| $F_3$ GENERATION | | | | | | | | | |
| 23 | 30-7 | 346 | 16 | 16 | 0 | 0 | 15 | 1 | 0 |

The $F_2$ progenies consist entirely of *Oe. pratincola* with red buds and the type of pubescence of the $F_1$ parent plant. The $F_3$ generation consists of *Oe. pratincola* with red buds, and shows the usual splitting in regard to pubescence.

## TABLE XXXII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (OF THE $F_1$ GENERATION OF THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*) × *Oe. pratincola* f. *typica* (GREEN BUDS, VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ red × $\alpha$ ♀ red; $\beta$ ♂ green → $\alpha$ red $\beta$ green. This is the reciprocal of the cross recorded in Table XXX

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 24 | 555 | 500 | 100 | 9 | 91 | 0 | 0 | 0 |

The progeny consists entirely of *Oe. pratincola*, 9 of the 100 plants having viscid pubescence. This unusual pubescence ratio has occurred in other cultures not involved in this paper, but it has not yet been explained.

## TABLE XXXIII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A SINGLE PLANT OF *Oe. pratincola* hyb. *typica* (WITHOUT VISCID PUBESCENCE) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION OF THE CROSS RECORDED IN TABLE XXXII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Green buds | | Red buds | | |
| | | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 24 | 7 | ca. 700 | 371 | 25 | 0 | 25 | 0 | 0 | 0 |

The progeny consists entirely of *Oe. pratincola* f. *typica*, except that among the seedlings there appeared one of mut. *nummularia*.

## TABLE XXXIV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS AND VISCID PUBESCENCE (OF THE $F_1$ GENERATION OF THE CROSS *Oe. pratincola* mut. *simulans* × *Oe. numismatica* f. *typica*) × *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (OF THE $F_1$ GENERATION OF THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*)

Constitutions: $\alpha$ ♀ red; $\beta$♂ green × $\alpha$ ♀ red; $\beta$♂ red → $\alpha$ red $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 25 × 26-7 | ca. 600 | 53 | 25 | 0 | 0 | 25 | 0 | 0 |

The culture consists entirely of *Oe. pratincola* mut. *simulans*. The pistillate parent has recovered the red bud color lost by its previous hybridization.

## TABLE XXXV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS AND VISCID PUBESCENCE (OF THE $F_1$ GENERATION OF THE CROSS *Oe. pratincola* mut. *simulans* × *Oe. numismatica* f. *typica*) × *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red; $\beta$♂ green × $\alpha$ ♀ red; $\beta$♂ green → $\alpha$ red $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 25 × 27-30 | ca. 800 | 4 | 4 | 4 | 0 | 0 | 0 | 0 |

This very small culture consists of *Oe. pratincola* mut. *simulans* with green buds.

## TABLE XXXVI

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (RESULTING FROM THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*) × *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS AND VISCID PUBESCENCE (RESULTING FROM THE CROSS *Oe. pratincola* mut. *simulans* × *Oe. numismatica* f. *typica*)

Constitutions: $\alpha$ ♀ red; $\beta$♂ red × $\alpha$ ♀ red; $\beta$♂ green → $\alpha$ red $\beta$ green. This is the reciprocal of the cross recorded in Table XXXIV

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 26-7 × 25 | 116 | 20 | 20 | 20 | 0 | 0 | 0 | 0 |

The progeny consists entirely of *Oe. pratincola* with viscid pubescence.

## TABLE XXXVII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE) × *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS AND VISCID PUBESCENCE (OF THE $F_1$ GENERATION OF THE CROSS *Oe. pratincola* mut. *simulans* × *Oe. numismatica* f. *typica*)

Constitutions: $\alpha$ ♀ red; $\beta$♂ green × $\alpha$ ♀ red; $\beta$♂ green → $\alpha$ red $\beta$ green This is the reciprocal of the cross recorded in Table XXXV

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 27-21 × 25 | 177 | 55 | 25 | 25 | 0 | 0 | 0 | 0 |

The culture consists entirely of *Oe. pratincola* with viscid pubescence.

## TABLE XXXVIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: THE SECOND HYBRID TYPE, OF $\alpha\alpha$ CONSTITUTION, RECORDED IN TABLE XXVIII, × *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (RESULTING FROM THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*)

Constitutions: $\alpha$ ♀ red and $\alpha$ ♀ green; $\alpha$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ red → $\alpha$ red $\beta$ red and $\alpha$ green $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 28 × 23-7 | 111 | 12 | 12 | 0 | 0 | 2 | 0 | 8 |

This culture of 10 plants consists of 2 plants of *Oe. pratincola* mut. *simulans*, and 8 of *Oe. numismatica* with buds classed as green but showing a slight mottling of red, indicating a slightly incomplete dominance.

## TABLE XXXIX

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: THE SECOND HYBRID TYPE, OF $\alpha\alpha$ CONSTITUTION, RECORDED IN TABLE XXVIII, × *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ red and $\alpha$ ♀ green; $\alpha$ ♂ green × $\alpha$ ♀ red; $\beta$ ♂ green → $\alpha$ red $\beta$ green, and $\alpha$ green $\beta$ green (missing from the progeny)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 29 × 27-30 | ca. 300 | 44 | 25 | 25 | 0 | 0 | 0 | 0 |

The progeny consists entirely of *Oe. pratincola* mut. *simulans* with green instead of red buds. It affords a departure from expectation, in that an expected class of plants of *Oe. numismatica* is entirely missing.

## TABLE XL

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (RESULTING FROM THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*) × THE SECOND HYBRID TYPE, OF $\alpha\alpha$ CONSTITUTION, RECORDED IN TABLE XXVIII

Constitutions: $\alpha$ ♀ red, $\beta$ ♂ red × $\alpha$ ♀ red and $\alpha$ ♀ green; $\alpha$ ♂ green → $\alpha$ red $\alpha$ green. This is the reciprocal of the cross recorded in Table XXXVIII

| Key number | Seeds planted | Germinations | Plants saved | Hybrid type of $\alpha\alpha$ constitution | | Other forms |
|---|---|---|---|---|---|---|
| | | | | Green buds | Red buds | |
| 26-7 × 29 | 162 | 37 | 25 | 25 | 0 | 0 |

The progeny consists entirely of plants of $\alpha\alpha$ constitution. The pubescence of this type cannot be put into either of the categories used in this paper.

## TABLE XLI

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* (GREEN BUDS, WITHOUT VISCID PUBESCENCE) × THE SECOND HYBRID TYPE, OF $\alpha\alpha$ CONSTITUTION, RECORDED IN TABLE XXVIII

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ green × $\alpha$ ♀ red and $\alpha$ ♀ green; $\alpha$ ♂ green → $\alpha$ red $\alpha$ green. This is the reciprocal of the cross recorded in Table XXXIX

| Key number | Seeds planted | Germinations | Plants saved | Hybrid type of $\alpha\alpha$ constitution | | Other forms |
|---|---|---|---|---|---|---|
| | | | | Green buds | Red buds | |
| 27-21 × 29 | ca. 400 | 72 | 25 | 4 | 0 | 0 |

The progeny consists of plants of $\alpha\alpha$ constitution. The pubescence of this type cannot be put into either of the categories used in this paper.

## TABLE XLII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* hyb. *typica* (RESULTING FROM THE CROSS *Oe. numismatica* f. *typica* × *Oe. pratincola* mut. *simulans*) × *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (RESULTING FROM THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*)

Constitutions: $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ red × $\alpha$ ♀ red; $\beta$ ♂ red → $\alpha$ green $\beta$ red

| Key number | Seeds planted | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 30 × 26-2 | ca. 425 | 33 | 25 | 24 | 0 | 0 | 0 | 0 |
| 31 × 26-7 | ca. 500 | 57 | 25 | 25 | 0 | 0 | 0 | 0 |
| TOTAL | ca. 925 | 90 | 50 | 49 | 0 | 0 | 0 | 0 |

The progenies consist entirely of *Oe. numismatica* f. *typica.* Nine of the plants of the first culture were recorded as having the form of the inflorescence somewhat more like *Oe. pratincola.*

## TABLE XLIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. numismatica* hyb. *typica* (RESULTING FROM THE CROSS *Oe. numismatica* f. *typica* × *Oe. pratincola* mut. *simulans*) × *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE)

Constitutions: $\alpha$ ♀ green; $\alpha$ ♂ green and $\beta$ ♂ red × $\alpha$ ♀ red; $\beta$ ♂ green → $\alpha$ green $\beta$ green

| Key number | Seeds planted | Germinations | Plants saved | *Oe. numismatica* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 30 × 32 | 49 | 43 | 25 | 25 | 0 | 0 | 0 | 0 |
| 31 × 27-30 | 320 | 175 | 25 | 25 | 0 | 0 | 0 | 0 |
| TOTAL | 369 | 218 | 50 | 50 | 0 | 0 | 0 | 0 |

The progenies consist entirely of *Oe. numismatica* f. *typica.*

## TABLE XLIV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE (RESULTING FROM THE CROSS *Oe. pratincola* f. *typica* × *Oe. pratincola* mut. *simulans*) × *Oe. numismatica* hyb. *typica*, RESULTING FROM THE CROSS *Oe. numismatica* f. *typica* × *Oe. pratincola* mut. *simulans*

Constitutions: $\alpha$ ♀ red; $\beta$♂ red × $\alpha$ ♀ green; $\beta$♂ red (and $\alpha$♂ green) → $\alpha$ red $\beta$ red (and $\alpha$ red $\alpha$ green)

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 26-2 × 30 | 19 | 17 | 17 | 0 | 0 | 16 | 0 | 1 |
| 26-7 × 31 | ca. 350 | 31 | 25 | 0 | 0 | 25 | 0 | 0 |
| TOTAL | ca. 369 | 48 | 42 | 0 | 0 | 41 | 0 | 1 |

The progenies consist of *Oe. pratincola* f. *typica* with red instead of green buds, and with viscid pubescence, except for one plant, with green buds, of the type interpreted as of $\alpha\alpha$ constitution.

## TABLE XLV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* f. *typica* (GREEN BUDS, WITHOUT VISCID PUBESCENCE) × *Oe. numismatica* hyb. *typica* (GREEN BUDS, VISCID PUBESCENCE) RESULTING FROM THE CROSS *Oe. numismatica* f. *typica* × *Oe. pratincola* mut. *simulans*

Constitutions: $\alpha$ ♀ red; $\beta$ ♂ green × $\alpha$ ♀ green; $\beta$ ♂ red (and $\alpha$ ♂ green) → $\alpha$ red $\beta$ red (and $\alpha$ red $\alpha$ green)

| Key number | Seeds planted | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 32 × 30 | 68 | 65 * | 25 | 0 | 0 | 24 | 0 | 1 |
| 27-21 × 31 | ca. 500 | 145 | 25 | 0 | 0 | 25 | 0 | 0 |
| TOTAL | ca. 568 | 210 | 50 | 0 | 0 | 49 | 0 | 1 |

With the exception of one plant, interpreted as of $\alpha\alpha$ constitution, the mature cultures consist of *Oe. pratincola* f. *typica* with red instead of green buds, and with viscid pubescence. It will be noted that both of the parents have green buds.

* Five of the discarded seedlings were of the type interpreted as of $\alpha\alpha$ constitution.

## TABLE XLVI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF TWO PLANTS OF *Oe. pratincola* hyb. *typica* WITH RED BUDS AND VISCID PUBESCENCE, CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XLV

| Key number | Parent plant | Germinations | Plants saved | *Oe. pratincola* | | | | Other forms |
|---|---|---|---|---|---|---|---|---|
| | | | | Green buds | | Red buds | | |
| | | | | Viscid pubescence | Without viscid pubescence | Viscid pubescence | Without viscid pubescence | |
| 32 × 30 | 1 | ca. 1,050 | 50 | 0 | 0 | 49 | 1 | 0 |
| 27-21 × 31 | 1 | ca. 550 | 50 | 0 | 0 | 50 | 0 | 0 |
| TOTAL | | ca. 1,600 | 100 | 0 | 0 | 99 | 1 | 0 |

The progenies consist entirely of *Oe. pratincola* f. *typica* with red instead of green buds, and show the usual segregation in regard to pubescence.

## TABLE XLVII

SUMMARY OF THE BUD COLOR AND BUD COLOR FACTORS OF PARENTS OF CROSSES INCLUDED IN THE PRECEDING TABLES

| Table Numbers | Bud color of pistillate parent | Bud color factor of ♀ gametes of pistillate parent | Bud color of staminate parent | Bud color factor of ♂ gametes of staminate parent | Bud color of $F_1$ and successive generations |
|---|---|---|---|---|---|
| XV, XVII, XXII, XXIV, XXXIX,* XLIII | green | green | green | green | green |
| XXVI, XXXVIII,* XLII | green | green | red | red | green |
| XIX, XXXV, XXXVII, XXXIX,* XLI | green | red | green | green | green |
| XLV | green | red | green | red | red |
| I, V, VII, XXX, XXXIV, XXXVIII * | green | red | red | red | red |
| IX, XI, XIII, XXVIII, XXXII, XXXVI, XL | red | red | green | green | green |
| XLIV | red | red | green | red | red |

* This table is included twice in this summary, since the pistillate parent of the cross which it tabulates produces eggs of two different constitutions.

# HETEROGAMETIC AND HOMOGAMETIC HYBRIDS BETWEEN TWO MUTATIONS OF *OENOTHERA PRATINCOLA**

FRIEDA COBB BLANCHARD

Introduction
The alpha-beta hypothesis
The nature of the problem
Two mutations of *Oe. pratincola* and their heterogametic and homogametic hybrids
Origin, characteristics and constitution of mut. *recidiva*
Origin, characteristics and constitution of mut. *simulans*
Reciprocal crosses between muts. *recidiva* and *simulans*
Characteristics of alpha-alpha and beta-beta hybrids
The functionings of alpha and beta as eggs and as sperms in back-crosses and crosses between the hybrid forms
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## INTRODUCTION

### *The Alpha-beta Hypothesis*

IN THE paper immediately preceding in this volume the hypothesis of heterogametism has been repeated at considerable length. It is, therefore, only very briefly stated here.

In *Oenothera pratincola* and its allies and mutations most plants are of alpha-beta constitution. Such plants are formed by the union of two unlike gametes, one alpha (usually the egg), and one beta (usually the sperm). The gametes produced by such a plant are like the gametes which went into its own make-up; that is, the chromosomes which entered in the egg remain

* Paper from the Department of Botany of the University of Michigan, No. 240.

together in the gametes formed, and those which entered with the sperm likewise remain together. Moreover, the assemblage of chromosomes which came in with the egg generally functions only as an egg, in the following haploid phase, and that which came in with the sperm generally functions only as a sperm. There are, however, exceptions to this rule, such as are dealt with in this paper.

The behavior of the alpha and the beta groups of chromosomes may be illustrated in the following simple way. Let the left hand represent an alpha gamete (egg) and the right hand a beta gamete (sperm), the fingers representing the chromosomes. Clasp the hands, forming a zygote. Let this zygote, in turn, produce gametes, by separating the hands. Two points will be noticed: first, the chromosomes of alpha have remained united together, and those of beta likewise — there has been no interchange of fingers between the right and left hands; second, the group of chromosomes which entered the zygote as an egg has come out again in the egg, and that which entered as a sperm has come out in the sperm — the left hand is still on the left side and the right hand on the right side.

The "alpha gamete" is the gamete which, in *Oenothera pratincola* and its allies, is responsible for the general form of the plant — the gamete which determines that a plant shall be *Oe. pratincola* f. *typica*, or mut. *simulans*, or mut. *recidiva*, etc. The alpha gamete generally functions as an egg, and, in general, all functioning eggs are alpha gametes. The alpha gamete is different in the different species and mutations; most mutations are due to changes in the alpha gamete. The alpha gamete of *Oe. pratincola* is called "pratincola alpha"; the alpha of mut. *simulans* is called "simulans alpha"; the alpha of mut. *recidiva* is called "recidiva alpha"; and so on. Each form has its own alpha. Any alpha-beta plant which has simulans alpha in its constitution is a simulans plant — either mut. *simulans*, if it is combined with a beta from simulans, or hyb. *simulans* if it is modified in some character by a beta from some other form. But a plant of alpha-alpha constitution combines the characters of the types supplying the two gametes. Regardless of the

sources of the gametes, such plants have a characteristic appearance, and can be recognized at a glance as alpha-alpha plants, though closer examination is necessary to determine what alpha gametes are combined in them. It is a rule that each kind of alpha has its own zygotic lethal, so that we do not have homozygous alpha-alpha plants, but only homogametic plants.

The beta gametes are identical or almost identical in a large series of forms, two members of which are the forms used as the basis of the investigation recorded in this paper. There are as many different alphas as there are species and mutations in this group; only four variations of beta are known. The four different betas are: beta of mut. *simulans,* carrying the factor for red buds instead of the factor for green; beta of mut. *nitidissima*, carrying the factor for red tips to the inflorescence axes, instead of the factor for green; beta of *Oe. pratincola* f. *typica* of strain Lexington E, and its mutations, carrying the factor for revolute leaves instead of that for flat leaves; and beta of *Oe. numismatica,* and of some mutations of *Oe. pratincola,* such as muts. *simulans, recidiva,* and various others, which carry the factor for viscid bud pubescence.

The factor for red buds in beta of mut. *simulans* is a recessive factor. The alpha gametes of *Oe. pratincola* and its mutations carry the factor for red bud color; the beta gametes carry the dominant factor for green buds, with the exception of mut. *simulans.*

The factor for red tips is either recessive, and occurs in all the alpha gametes, but in beta only in mut. *nitidissima,* the beta gametes of the other forms carrying the dominant factor for green tips; or, the factor for red tips is dominant, and is present in beta of mut. *nitidissima* alone, not in other beta gametes nor in alpha gametes.

The factor for revolute leaves has recently been discovered to be in beta of the strain of *Oe. pratincola* known as Lexington E. It is recessive. All alpha gametes so far combined with this beta, and all other beta gametes, have the dominant factor for flatness.

The location and behavior of the pubescence factors is not understood.

Combinations of two identical beta gametes are lethal or nearly so.

Besides the chromosomes which are confined to the alpha and beta groups, there may be some which are free. Such independent pairs of chromosomes segregate freely, showing no association with alpha and beta. If such chromosomes exist, either they are not concerned with the general differences which separate the different forms, or, in crosses, they find no homologous mates. In the latter case, the chromosomes might segregate freely within a given form, but not in its hybrids. The number of free chromosomes is probably different in different species and mutations. There is no proof that all of the factors responsible for the different species and mutations are not in a single chromosome, and that alpha is therefore but a single chromosome, the other six pairs segregating freely. If this is the case, all the forms, with few exceptions, must be homozygous as far as the other six chromosomes are concerned.

Whether the alpha assemblage, responsible for the type of a plant, is a single chromosome, or all seven chromosomes, or an intermediate condition, a gamete carrying this assemblage, whether or not it carries any free chromosomes, is called an alpha gamete. In previous papers the expression "characteristic portion of the alpha gamete" has been used to designate the chromosomes which remain together as a unit specific for the different forms.

### *The Nature of the Problem*

The paper referred to above dealt with the inheritance of bud color, one of the few characters which we have been able to separate from the general complex of characteristics which make up a species or a mutation. This character, bud color, is one of the few which we can show to depend on a pair of factors, one carried by, and confined to, alpha; the other to beta. Such a condition naturally produces matroclinic or patroclinic behavior. Several earlier papers have dealt with a separable character (revoluteness of the leaves) of another type; a character determined by a pair of factors, one carried in the egg, the other in

the sperm, but neither one of the pair confined to either gamete, i.e., factors in freely segregating chromosomes. This character, of course, showed Mendelian behavior. The present paper does not deal with the inheritance of a single visible characteristic, but with the inheritance, as a whole, of the complex assemblage of so far inseparable features which, irrespective of the few separable characteristics, make up the types known as *Oe. pratincola* muts. *recidiva* and *simulans*. This inheritance depends on the assemblages of chromosomes known as alpha and beta, and on the comparative survival values of differently constituted alpha and beta gametes and their effects upon one another.

Mut. *simulans* is the form in which originated the red bud color which was the material of the work recorded in the paper immediately preceding in this volume. The results of the crosses between muts. *simulans* and *recidiva*, which form the subject of this paper, might have been included in the earlier paper. However, the constitutions of alpha and beta in mut. *recidiva* made the results of these crosses more complex, and difficult to treat of with the simpler crosses of that paper. It is partly through the behavior of the red bud character, worked out in simpler cases, that the behavior of the alpha and beta gametes is demonstrated here.

In the two forms used in the present investigation, as in *Oe. pratincola* f. *typica* and its allies, it is the alpha gamete which determines the type of plant. In mut. *simulans* this gamete is therefore called simulans alpha, and in mut. *recidiva*, recidiva alpha. The beta gametes of both forms give results identical with those produced by the beta of *Oe. pratincola* f. *typica*, except that they both carry a factor for viscid bud pubescence, instead of a factor for its absence, and the beta of mut. *simulans* carries the factor for red bud color instead of that for green. The differences between the two forms are: the differences between simulans alpha and recidiva alpha, the bud color factors in beta, and the differences in survival values as eggs and as sperms of the two kinds of alpha.

## TWO MUTATIONS OF *Oe. pratincola* AND THEIR HETEROGAMETIC AND HOMOGAMETIC HYBRIDS

### *Origin, Characteristics and Constitution of Mut. recidiva*

Mut. *recidiva* arose from strain I of *Oe. pratincola*, through mut. *nummularia*, in 1916. Its pedigree is as follows: *Oe. pratincola* strain Lexington I – 13 *nummularia* – 3 *nummularia* (open-pollinated) – 5 *recidiva*. The constitutions of the progenies in each generation are given in Table II.

Mut. *recidiva*, unlike the true-breeding mut. *simulans*, produces in every generation a progeny consisting of two types: mut. *recidiva*, and a stunted, frequently irregular-leaved, gray form, which never grows more than a few inches high, and never flowers. These plants have been recorded as "runts." The type is a perfectly definite one; the plants are alike, not a heterogeneous group of weakling forms. They contrast very strikingly with the big, green, luxuriant plants of mut. *recidiva*. The ratio of the two types varies in different seasons. Table III shows the proportions in the different generations.

Mut. *recidiva* is a heterogametic form in which both alpha and beta eggs, and both alpha and beta sperms, function, in more or less equal numbers. It is estimated from the results of various crosses that more beta than alpha eggs function, and that more alpha than beta sperms function. The alpha gamete responsible for this form is designated recidiva alpha; the beta gamete is the beta of *Oe. pratincola* and its mutations except that it carries a factor for viscid pubescence.

Plants of recidiva alpha-alpha constitution are non-viable; recidiva beta-beta zygotes are non-viable or may develop into miserable, sterile dwarf plants. Mut. *recidiva*, therefore, produces in every generation two types of plants: alpha-beta and beta-alpha plants, identical, and resembling the parent plant; and beta-beta plants, dwarfs, which should breed true if they were not sterile.

Included in recidiva alpha is a factor for red bud color, and included in beta of mut. *recidiva* is a factor for green bud color.

In every generation mut. *recidiva* produces a few plants lacking the viscid pubescence, and these plants breed true to this character (see Table III). This character is recorded in the tables, but is not yet understood. It will be a topic for later discussion.

*Origin, Characteristics and Constitution of Mut. simulans*

Mut. *simulans* used in these crosses arose from strain C of *Oe. pratincola,* in 1915. Its pedigree is as follows: *Oe. pratincola,* strain Lexington C – 22 – (15 *nitida* × 10) – 1 *simulans.* The single plant of mut. *simulans* was one of a culture of four plants, the others being mut. *nitida.*

Mut. *simulans* is heterogametic, but, with occasional exceptions, only alpha eggs function, and only beta sperms. The alpha gamete resulting in the production of this form is designated simulans alpha; the beta gamete is the beta of *Oe. pratincola* and its mutations, except that it carries the factor for red buds instead of that for green buds, and a factor for viscid pubescence. Like recidiva alpha, simulans alpha carries a zygotic lethal, the alpha-alpha combination being non-viable; and beta carries a factor which likewise makes non-viable a beta-beta zygote. Mut. *simulans,* therefore, breeds true, only alpha-beta zygotes surviving.

Included in simulans alpha is the factor for red bud color, which, so far as is known, is always present in pratincola alpha. The same factor occurs in simulans beta, but this is in contrast to the usual condition, for beta of most forms carries the dominant factor for green buds.

Mut. *simulans* is a form in which the functioning eggs are generally alpha and the sperms generally beta, but it has been shown that, at least in some instances, about one and one half per cent of the eggs which function are beta gametes, and about one per cent of the sperms are alpha gametes.

It is probable that, when mut. *simulans* arose, there went into it a beta gamete in which a chromosome from alpha had been exchanged with one of beta (a "whole-chromosome crossover") making a beta gamete containing one chromosome identical with one in the alpha gamete. (This of course may have been only part of the change involved.)

*Reciprocal Crosses between Muts. recidiva and simulans*

In mut. *recidiva* both alpha and beta eggs and alpha and beta sperms function. By self-pollination it produces alpha-beta and beta-alpha plants, like itself, and also beta-beta plants, which are miserable runts. The alpha-alpha plants do not appear, because of a zygotic lethal in alpha. The beta-beta combination is sub-lethal. The proportion of plants of mut. *recidiva* and beta-beta runts varies greatly in different progenies, as may be seen in Table III. If alpha and beta eggs functioned in equal numbers, and alpha and beta sperms likewise, there should be twice as many plants of mut. *recidiva* as of runts. Runts, however, predominate.

In mut. *simulans*, alpha eggs and beta sperms function, with a small percentage of beta eggs and alpha sperms. Aside from rare mutations with which we are not at present concerned, mut. *simulans* produces, by self-pollination, only alpha-beta plants like itself. No runts occur, because beta eggs do not function here as they do in mut. *recidiva*. When beta-beta plants are produced by crossing, with both betas originally from mut. *simulans*, they are runts, as in the case of beta-beta plants from mut. *recidiva*.

Each of the reciprocal crosses between muts. *recidiva* and *simulans* gives twin hybrids. The two types of one progeny, however, are quite different from the two types of the reciprocal progeny. In each case the first twin is like the female parent, but with the bud color of the male parent; and the second twin, in each case, is something quite new. In each progeny, however, there are a very few (metaclinic) plants of each of the two types resulting from the reciprocal cross.

Mut. *recidiva* × mut. *simulans* →

(1) hyb. *recidiva* with red buds (recidiva alpha, simulans beta)
(2) beta-beta hybrid, a tall, cylindrical, heavy, gray type (beta from mut. *recidiva*, beta from mut. *simulans*)
(3) a small number of plants like each of the types of the reciprocal cross

Mut. *simulans* × mut. *recidiva* →

(1) hyb. *simulans* with green buds (simulans alpha, recidiva beta)
(2) alpha-alpha hybrid, a slender, low *nutans*-like type (simulans alpha, recidiva alpha)
(3) a small number of plants like each of the types of the reciprocal cross

By self-pollination, the red-budded hyb. *recidiva* produces two types: plants like itself, and runts. The green-budded hyb. *simulans* breeds true.

By self-pollination, the beta-beta hybrid gives plants like itself, runts and intermediates (see Tables VIII and XIV, and discussion on page 142). By self-pollination, the alpha-alpha hybrid gives in every generation plants like itself and plants which die as very young seedlings (see Tables XII, XXXIV and XLIV and discussion on page 145).

The reversal of bud color in the $F_1$ hyb. *recidiva* and hyb. *simulans* repeats the behavior recorded in the paper immediately preceding in this volume. The explanation may be stated here briefly as follows: Recidiva alpha, simulans alpha, and beta of mut. *simulans* all carry the recessive factor for red bud color. Beta of mut. *recidiva* carries the dominant factor for green buds. In crosses between muts. *simulans* and *recidiva*, then, the beta gamete determines the bud color, except in the case of beta-deta plants from the cross mut. *recidiva* × mut. *simulans*. The bud color of beta-beta plants is inconspicuous, because of the very dense pubescence of this type, and has not been carefully recorded. It is known, however, that in the $F_2$ generation from such an $F_1$ plant (beta-beta) there is a segregation in regard to bud color, doubtless a simple Mendelian segregation. All alpha-alpha plants so far observed lack red bud color, regardless of the constitutions of the alpha gametes concerned.

### *Characteristics of Alpha-alpha and Beta-beta Hybrids*

It is the alpha gametes which are responsible for the form of the plant, except so far as the four known beta factors may modify it. Therefore alpha-alpha hybrids have the combined appearance of the two forms represented. Any alpha-alpha plant has a characteristic appearance which is easily recognizable. On closer examinations the characters of the two parent forms can be distinguished, and, at least in many cases, the parentage can be determined without help from the records.

The characteristics of the two kinds of homogametic plants are as follows:

| | PLANTS OF ALPHA-ALPHA CONSTITUTION | PLANTS OF BETA-BETA CONSTITUTION |
|---|---|---|
| Character of plant if gametes are identical: | Not germinating, or, if germinating, seedling dying before first leaves appear | At best a runt, a few inches high, with irregular leaves, and almost never flowering |
| Character of plant if gametes are not identical: | Varying according to the gametes concerned, combining the characteristics of the two forms supplying the gametes. Slender in all parts, dainty, brittle-looking, low, broad, early-flowering; sometimes nearly or completely sterile | Varying only in the four characteristics mentioned on page 135. Very thick and heavy in all parts, very tall, cylindrical (side branches few and erect), late-flowering, always fertile |
| Color of plant: | Green, often yellowish-green | Always gray |
| Inflorescence: | Dense, with many side-inflorescences; axis very slender | Very long and lax, without side-inflorescences; axis exceedingly thick |
| Bracts: | Very small, frequently deciduous | Large and leaf-like, greatly exceeding and concealing the buds; persistent |
| Flowers: | Small and very slender | Large, with very thick hypantheum |
| Pubescence of flowers: | Never dense; crispate pubescence entirely lacking; tendency to be glabrous except for long, variously directed hairs especially conspicuous at angles of buds; viscid pubescence, if present, sparse | *Very* dense short crispate pubescence |
| Red pigment of buds and tips of inflorescence axes: | Red always lacking, regardless of the constitution of the plant | Pigment showing, when factors are present, but inconspicuous on account of the exceedingly dense crispate pubescence |

### *The Functionings of Alpha and Beta as Eggs and as Sperms in Back-crosses and Crosses between the Hybrid Forms*

Tables XV to XLVI show the results of the crosses among the four hybrid types, and between them and the two parents. Table XLVII is a summary of these tables, in which are indicated the few discrepancies between the expected and the actual results. These discrepancies are discussed on page 149.

The reciprocal crosses among the four hybrid and two parental types show the following condition of the functioning of alpha and beta gametes as eggs and sperms.

#### *Eggs*

In mut. *recidiva*, both alpha and beta eggs function. This is shown in the various tables which record mut. *recidiva* as egg parent (VI, XV, XXIII, XXVII). In the tables referred to, the ratio of alpha to beta eggs is 1 to 7.

When recidiva alpha is combined with beta of mut. *simulans* both alpha and beta gametes function as eggs. That recidiva alpha eggs function is shown by Table XXV. That the beta eggs function is shown by Tables XXV and XL, and by the presence of runts in the $F_2$ and following generations recorded in Tables VII, XIII, XVII (very few), XXI, XLI [1] and XLVI.

When recidiva alpha is combined with simulans alpha, both kinds of gametes function as eggs (Tables XXXII, XLII, XLV). But the recidiva alpha eggs are comparatively few. In the cross recorded in Table XXXV no recidiva alpha eggs functioned. The eleven plants of the progeny all came from simulans alpha eggs. In the three tables showing the functioning of both kinds of eggs, the proportions of simulans alpha to recidiva alpha are 57 to 2, 3 to 1, and 6 to 3. It is, therefore, not surprising that in one case, in a progeny of eleven, no recidiva alpha egg functioned.

In mut. *simulans*, in general only alpha eggs function. This is shown in the various tables which record mut. *simulans* as

[1] There is a single plant in the culture, and two types are expected. The plants which died were doubtless runts, making the second type.

egg parent (X, XXXVI, XXXVII, XXXVIII) and by very many other crosses not connected with this piece of work. That beta eggs occasionally function is shown in Tables X and XXXVI, by the presence in the $F_1$ progenies of two beta-beta hybrid plants and five plants of hyb. *recidiva* with red buds in Table X, and of ten beta-beta hybrid plants in Table XXXVI. The ratio of alpha eggs to beta eggs, calculated from these tables, is 66 to 1.

When simulans alpha is combined with beta from mut. *recidiva* the eggs which function are still all alpha gametes (see Tables XXVIII and XLIV). When a plant has a beta-beta constitution, with one beta from mut. *recidiva* and one from mut. *simulans*, it produces functioning eggs of both kinds (see Tables XIX and XXXIX).

*Sperms*

In mut. *recidiva*, both alpha and beta sperms function. This is shown in the various tables which record mut. *recidiva* as male parent (X, XIX, XXV, XXVIII, XXXII), and by many other crosses made in the garden. In the tables referred to, the ratio of beta sperms to alpha sperms is 1 to 1.

When recidiva alpha is combined with simulans beta both alpha and beta sperms still function (Tables XXXVIII, XLII). In the progeny of the cross recorded in Table XXIII, plants of mut. *recidiva*, resulting from recidiva alpha sperms, would be expected but do not occur. This progeny, however, consists of only two plants, and three types are expected. On the contrary, in the cross recorded in Table XXXIX no beta sperms functioned. Since, however, the progeny consisted of only five plants, and three types were expected, the numbers were obviously insufficient for the case to bear any weight.

When recidiva alpha is combined with simulans alpha, only the former functions as sperms (Tables XXX, XL). In Tables XII, XXXIV and XLIV groups of lethal seedlings are recorded. If these plants are simulans alpha-alpha, simulans alpha must function as a sperm. This matter is discussed on page 145.

In mut. *simulans*, in general only beta sperms function. This is shown in the two tables which record mut. *simulans* as

male parent (VI, XXXV), and by very many other crosses with which this paper is not concerned. That alpha sperms occasionally function is shown in Table VI by the occurrence of four plants of hyb. *simulans* with green buds and one alpha-alpha hybrid. The ratio of beta to alpha sperms in mut. *simulans*, as shown by this table, is 108 to 1.

When simulans alpha is combined with beta from mut. *recidiva*, there seems to be an increase in the proportion of functioning alpha sperms. In Table XXVII, the presence of two plants of hyb. *simulans* with green buds, in a progeny of 53 plants, shows the functioning of 51 beta sperms to two alpha sperms. In the progeny of the cross recorded in Table XLV we should expect some alpha-alpha hybrids to result from the alpha sperms, but there are only nine plants in the culture, which is too small a number to include this class. When combined with recidiva alpha, simulans beta eggs function as numerously as do recidiva beta eggs; yet, when combined with recidiva beta, simulans alpha sperms do not function as readily as recidiva alpha sperms.

When a plant has a beta-beta constitution, with one beta from mut. *recidiva* and one from mut. *simulans*, it produces functional sperms of both kinds (Tables XV, XXXVII).

### *White Seedlings, Pale Seedlings and "Lethals"*

Alpha-alpha hybrids are frequently variegated. Roughly, one mature plant in five shows a lack of chlorophyll which varies from a few white streaks in a few leaves to complete whiteness in a large part of the plant. These variegated plants may often be detected as seedlings, as soon as the cotyledons unfold. Because of this tendency, it is assumed that the "white seedlings" (Tables XII, XXXIV and XLIV) are merely extremes of this variation. "Pale seedlings" (Table XII) are supposed to be either another aspect of the lack of chlorophyll in alpha-alpha plants, or mutations of some kind.

In three tables, XII, XXXIV and XLIV, a seedling type called "lethal" is recorded. Seedlings of this type are tall and slender, and very dark colored. The cotyledons do not expand. These seedlings may stand several days, without growing, but

finally wither and the stem collapses. Of the three tables in which this type is recorded, two (XII and XXXIV) record self-pollinations of alpha-alpha hybrids, and one (XLIV) records the cross hyb. *simulans* with green buds × alpha-alpha hybrid. They must, therefore, be of alpha-alpha constitution. If they are recidiva alpha-alpha, they should occur in progenies from self-pollinated mut. *recidiva*, and also in the cultures of nine other tables in which they do not occur; and, moreover, they could not occur in one instance in which they do (Table XLIV). If they are simulans alpha-alpha, they should occur also in the cultures of two other tables, XXX and XL, and we would have simulans alpha functioning equally with recidiva alpha as sperms in plants of recidiva alpha simulans alpha constitution. If the lethals are of recidiva alpha simulans alpha constitution, there must be a freely segregating chromosome pair concerned, as many zygotes of this constitution survive.

It is realized now that only where they were conspicuous were the lethal seedlings recorded; they were not hunted for. These seedlings are so short-lived that, especially where they are not numerous, they might be overlooked. Evidently the seedling records are not complete.

The probability is that lethal seedlings are of simulans alpha-alpha constitution; that they occurred in the two cultures recorded in Tables XXX and XL, but were overlooked or not recorded; and that simulans alpha functions as a sperm when in combination with recidiva alpha. The occurrence of this type in the progenies of some other crosses, with which this paper is not concerned, also lends weight to this probability.

### *Factor Determining the Functioning or Non-functioning of Alpha and Beta Gametes as Eggs and Sperms*

In mut. *recidiva*, both alpha and beta gametes function as both eggs and sperms; in mut. *simulans*, with rare exceptions, beta gametes do not function as eggs, and alpha gametes do not function as sperms. Reciprocal crosses between the two forms give twin hybrids in each case, four types in all. This is because of the two types of gametes in both ovules and pollen of mut.

*recidiva*. The few functioning beta eggs and alpha sperms in mut. *simulans* are revealed by the presence in each hybrid culture of a few plants of the type belonging to the reciprocal culture (see Tables VI and X).

It has been suggested that there is something about the alpha in most forms which prevents it from functioning as a sperm (except rarely, perhaps following a crossing-over), and similarly something about beta which makes it unsuitable as an egg. Alpha gametes of *Oe. pratincola* and its mutations have been said to contain a "pollen lethal"; and the exceptional gametes have been considered to have lost the lethal factor.

But it has been found that, though beta gametes of mut. *simulans* do not function as eggs in uncrossed mut. *simulans*, they *do* function as eggs with recidiva alpha, instead of simulans alpha (that is, in hyb. *recidiva* having alpha from mut. *recidiva* and beta from mut. *simulans*); and, similarly, though beta gametes of mut. *recidiva* may function as eggs in uncrossed mut. *recidiva*, they do *not* do so when with simulans alpha, instead of recidiva alpha (in hyb. *simulans*, with alpha from mut. *simulans* and beta from mut. *recidiva*). For example, with sperms of the same constitution in the two cases simulans beta eggs function when produced in association with recidiva alpha eggs, but not when with simulans alpha eggs. In the progenies recorded in Table X (mut. *simulans* × mut. *recidiva*) only 7 out of the 923 plants came from simulans beta eggs, the other 916 resulting from simulans alpha eggs. But in the cross recorded in Table XXV, hyb. *recidiva* with red buds (i.e. recidiva alpha simulans beta) × mut. *recidiva*, of which the pollen parent is the same, and the functioning sperms also identical, 26 plants (mut. *recidiva*) resulted from the recidiva alpha eggs and 17 plants (the 2 of hyb. *recidiva* and the 15 beta-beta hybrids) from the simulans beta eggs. Also, in Table XL, hyb. *recidiva* with red buds (i.e. recidiva alpha simulans beta) × alpha-alpha hybrid, 28 plants of hyb. *recidiva* (the whole progeny except for one mutation) resulted from the simulans beta eggs, the recidiva alpha eggs failing to contribute to the progeny because they were fertilized by sperms exactly like themselves.

And there is some evidence (see Table XXVII) that simulans alpha can function as a sperm when combined with beta of recidiva, just as does recidiva alpha.

So it is demonstrated that it is not inability ever to function as an egg which keeps beta from so functioning in *Oe. pratincola* and its mutations; beta eggs capable of being fertilized and producing good seeds occur in the same numbers as do alpha eggs. Nor is it the constitution of the male gamete with which they are fertilized which prevents the beta eggs from producing seeds, except so far as they are prevented by the non-viability of zygotes composed of two identical gametes.

*It is the gametes with which they are associated, the eggs of the other type, which determine whether or not the beta eggs shall produce seeds.* Not all the eggs produce seeds. In *Oe. pratincola* and its mutations (with the exception of mut. *recidiva*) the alpha eggs flourish at the expense of the beta eggs. In mut. *recidiva* both types of eggs produce seeds. In mut. *simulans*, beta eggs rarely produce seeds. But that beta of mut. *simulans* is capable of making good seeds is shown by the fact that in hybrid plants of the constitution recidiva alpha simulans beta, where simulans beta is produced concurrently not with simulans alpha but with the comparatively weak recidiva alpha, beta eggs produce their share of the seeds. Moreover, beta of mut. *recidiva*, which functions as an egg when produced with recidiva alpha, when concurrent with simulans alpha does not produce seed.

Plants of beta-alpha constitution are very interesting in this connection. They are identical with plants of alpha-beta constitution, but receive the alpha from the male parent and the beta from the female, instead of the reverse. Such plants appear usually to function just as do plants of non-metaclinic origin, that is, they produce a vast majority of functional alpha eggs and beta sperms.

The strength of any gamete as an egg varies inversely as its strength as a sperm. Thus a gamete which is very strong as an egg is very weak as a sperm; one which is moderately strong as an egg is moderately weak as a sperm, and one which is weak as an egg is strong as a sperm. Briefly, the relative values of the various gametes with which we are dealing are as follows:

| GAMETES AS EGGS | GAMETES AS SPERMS |
|---|---|
| recidiva alpha < recidiva beta | recidiva alpha = recidiva beta |
| recidiva alpha = simulans beta | recidiva alpha = simulans beta |
| recidiva alpha < simulans alpha | recidiva alpha > simulans alpha |
| simulans alpha > simulans beta | simulans alpha < simulans beta |
| simulans alpha > recidiva beta | simulans alpha < recidiva beta |
| simulans alpha > recidiva alpha | simulans alpha < recidiva alpha |
| recidiva beta > recidiva alpha | recidiva beta = recidiva alpha |
| recidiva beta < simulans alpha | recidiva beta > simulans alpha |
| recidiva beta = simulans beta | recidiva beta = simulans beta |
| simulans beta < simulans alpha | simulans beta > simulans alpha |
| simulans beta = recidiva alpha | simulans beta = recidiva alpha |
| simulans beta = recidiva beta | simulans beta = recidiva beta |

There seems to be some variation in the relative values of recidiva alpha and recidiva beta as eggs and as sperms. Otherwise, the rule of inverse values as eggs and sperms seems to hold.

To sum up, the sex limitations of alpha and beta are due not to something within the constitutions of the gametes themselves, but, rather, either to selective fertilization, one type having greater selective value as an egg, the other as a sperm, or to different survival values after fertilization, one type developing at the expense of the other. In mut. *simulans*, for example, the alpha eggs develop at the expense of the beta eggs; but as sperms, the beta gametes exclude the functioning of the alpha gametes in this form. In mut. *recidiva* the alpha eggs cannot so monopolize the situation; neither do the beta sperms prevent the functioning of the alpha sperms.

### *Conformity of the Progenies with Expectation*

On the basis of the constitutions hypothecated, and the comparative survival strengths of the various gametes, the only cases in which an expected type fails to appear are in small cultures, or cultures too small to have the type represented, as follows:

1. In Table XXXV, alpha-alpha hyb. × mut. *simulans*, two types are expected, hyb. *recidiva* with red buds and mut. *simulans* (red buds). Fewer of the former than of the latter are expected. In the culture of 11 plants, none of the former appeared.

2. In Table XXXIX, beta-beta hyb. × hyb. *recidiva* with red buds, four types are expected, mut. *recidiva*, hyb. *recidiva* with red buds, beta-beta hybrid, and runt. In the culture of 5 plants no beta-beta hybrids nor runts occurred.

3. In Tables IX, XVI, XXVI and XLI, some runts are expected but are not recorded. In Tables IX, XXVI and XLI, they are doubtless represented by the plants that did not reach maturity, those recorded in the "dead" column. No explanation can be offered for the absence of the class in the first case, a progeny of 22 plants.

4. In the crosses recorded in Tables XLV and XXVII we might have had alpha-alpha hybrids resulting from the rare simulans alpha sperms, but in these progenies, of only 9 plants in the first case, and 53 in the second, we should not expect any to occur.

5. In Table XXIII, mut. *recidiva* × hyb. *recidiva*, three types are expected: mut. *recidiva*, hyb. *recidiva* with red buds, and beta-beta hybrid. In the culture of two plants, no mut. *recidiva* occurred.

## *Summary*

1. The two forms used are both heterogametic, that is, are of alpha-beta constitution.

2. It is the alpha gamete which determines the form of the plant. In determining the appearance of the plant, except for bud color, the source of the beta gamete is immaterial. There are no characteristics of these plants depending on freely segregating chromosomes.

3. In *Oe. pratincola* mut. *recidiva*, the two kinds of gametes produced, alpha and beta, have about equal survival values as both eggs and sperms. In this form, then, both alpha and beta eggs function, and both alpha and beta sperms.

4. In *Oe. pratincola* mut. *simulans*, the alpha gametes have far greater survival value than the beta gametes as eggs, and far less as sperms. In this form, therefore, only alpha eggs and only beta sperms function (with rare exceptions).

5. The combination of two identical alpha gametes is lethal, at best surviving only to the time of the opening of the coty-

ledons. Two different alpha gametes combine readily and make a vigorous plant.

6. The combination of two identical beta gametes makes a weak, much dwarfed plant (runt) which does not flower. Two beta gametes from different sources, differing only, so far as appearance shows, in the factor for bud color, combine readily and make an exceptionally fine large plant.

7. Reciprocal crosses between muts. *recidiva* and *simulans* give, in both cases, twin hybrids, but the two forms in one progeny are different from the two forms of the other. In each progeny are a very few plants of the two forms belonging to the reciprocal cross.

8. In each of the $F_1$ cultures, one hybrid form is heterogametic (like the egg parent but with the bud color of the pollen parent (see the paper immediately preceding in this volume)), and the other form is homogametic, in one case of alpha-alpha constitution, in the other case of beta-beta.

Mut. *recidiva* produces functional alpha and beta eggs; alpha and beta sperms.

Mut. *simulans* produces functional alpha (and occasional beta) eggs; beta (and occasional alpha) sperms.

recidiva × simulans → { alpha-beta plants (hyb. *recidiva*, like egg parent except in bud color) ; beta-beta plants }

simulans × recidiva → { alpha-beta plants (hyb. *simulans*, like egg parent except in bud color) ; alpha-alpha plants }

9. Plants of alpha-alpha constitution, whatever the constitution of the gametes involved, can be recognized at a glance. They are low, spreading, slender in all their parts, with a tendency to be glabrous. Likewise plants of beta-beta constitution are very distinctive and always recognizable, whatever the source of the gametes. They are tall, cylindrical, heavy, gray and densely crispate-pubescent.

10. Crosses between the hybrid forms and back-crosses show that though the gametes have remained intact in the hybrid forms, that is, the combinations of chromosomes have apparently not been rearranged by crossing, the abilities of the different

gametes to function as eggs and as sperms have been changed in the new combinations of gametes. For example, beta of mut. *simulans*, which does not function as an egg when with simulans alpha, does function when with recidiva alpha, just as does beta of mut. *recidiva*.

11. It is, therefore, concluded that it is not an inability ever to function as an egg which keeps female beta gametes of *Oe. pratincola* and its mutations from producing seed, but rather the eggs of the other kind, with which they are in competition. Replace the gamete with which it is combined by one of a different constitution, and the ability of beta to function as an egg may be changed. Some gametic constitutions are stronger as eggs than others. Similarly, some gametic constitutions are stronger than others as sperms. In general, the relative strength of two gametes as sperms is the inverse of their relative strength as eggs.

12. Recidiva alpha, beta of mut. *recidiva*, and beta of mut. *simulans*, all have about equal survival values, both as eggs and as sperms. Simulans alpha has greater survival value as an egg than recidiva alpha, beta of mut. *recidiva*, and beta of mut. *simulans*; and less value as a sperm. The relative values of the gametes with which this paper is concerned are given on page 149.

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## EXPLANATIONS APPLYING TO ALL THE TABLES

The constitutions given in connection with the tables are in respect to alpha and beta, sex, and bud color only.

The bud color factors might be expressed in the usual way, *G* and *g*, but since their behavior is not Mendelian this has not been done.

Bud color and bud pubescence are merely recorded in the tables of this paper, not discussed. In respect to bud color the results are entirely in accord with the results and conclusions already recorded (see the paper immediately preceding in this volume). The inheritance of the pubescence is being studied, but is not yet understood.

The constitutions given above each table are those hypothecated in the text of the paper. The gametic constitutions of the parents are given, and are followed by the theoretically possible zygotic constitutions of their progeny. The comparative survival strengths of the various gametes are considered. Only viable combinations of gametes are listed; combinations of two identical alpha gametes are omitted.

It is supposed that beta of mut. *simulans*, like beta of mut. *recidiva*, can function as an egg when combined with recidiva alpha, and that hyb. *recidiva* with red buds can, therefore, always produce runts, just as uncrossed mut. *recidiva* does; and that beta of mut. *recidiva*, like beta of mut. *simulans*, cannot function as an egg when combined with simulans alpha.

There is some evidence that simulans alpha can function as a sperm when combined with beta of mut. *recidiva*, just as recidiva alpha does, but such simulans alpha male gametes, if they do occur, have not been taken into account in listing the expectations. There is only one table which throws light on this matter, Table XXVII, and this single cross indicates, by producing two plants of hyb. *simulans* with green buds, that, when combined with beta of mut. *recidiva*, simulans alpha may function as a sperm more often than in uncrossed mut. *simulans*.

In giving the gametic constitution of mut. *simulans* and expected results from its crosses, the possibility of the functioning of beta eggs and alpha sperms has been disregarded. When, however, metaclinic hybrids have actually occurred, attention is called to the fact. When they have not occurred, it is obviously in accordance with expectation.

Following is a list of the mutations occurring in the cultures considered in this paper. They are all forms which occur normally in one or the other of the two strains used in the experiment: *albida*, *angustifolia*, "*debilis*-like," *ericacea*, *fallax*, *graminea*, *gravida*, *grisea*, *grisella*, *nitida*, *nummularia*, "*rigida*-like," *sublatifolia*, *tortuosa*.

Except for mut. *fallax*, these forms occurred with the frequency which would be expected. The number of plants of mut. *fallax* seems to be increased by crossing. This is a subject for further study.

## TABLE I

RECORD OF THE PARENTAGE OF ALL THE PROGENIES RECORDED IN THE FOLLOWING TABLES, WITH KEY NUMBERS

**1.** Mut. recidiva – 97
×
mut. simulans – 25 – 33

**2.** Mut. recidiva – 28
×
mut. simulans – 25 – 34 – 1

**3.** Mut. recidiva – 28
×
mut. simulans – 3 – 20 – 11

**4.** Mut. recidiva – 29
×
mut. simulans – 3 – 20 – x

**5.** Mut. simulans – 25 – 33
×
mut. recidiva – 97
(reciprocal of 1)

**6.** Mut. simulans – 25 – 34 – 1
×
mut. recidiva – 28
(reciprocal of 2)

**7.** Mut. simulans – 3 – 20 – 10
×
mut. recidiva – 29

**8.** Mut. recidiva – 29

**9.** Mut. recidiva – 11 – 76

**10.** Mut. recidiva – 51 – 4 – 17 – 15

**11.** Mut. recidiva – 28

**12.** Mut. simulans 25 – 33 × mut. recidiva – 97 } – 57 alpha-alpha hybrid × mut. recidiva – 29

**13.** Mut. simulans – 25 – 33 – 10

**14.** Mut. simulans – 25 – 33 × mut. recidiva – 97 } – 6 alpha-alpha hybrid × mut. recidiva – 97 × mut. simulans – 25 – 33 } – 11 hyb. recidiva with red buds

TABLE I (*continued*)

**15.** Mut. recidiva – 51 – 4 – 17 – 15 – 19 – 5 – 7 – 2
×
mut. simulans – 24 – 2 – 29 – 9 – 4 – 19 – 5 – 16 – 14

**16.** Mut. simulans – 24 – 2 – 29 – 9 – 4 – 19 – 5 – 16 – 14
×
mut. recidiva – 51 – 4 – 17 – 15 – 19 – 5 – 7 – 2
(reciprocal of 15)

**17.** Mut. recidiva – 28 × mut. simulans – 3 – 20 – 11 – 30 – 16 – 1 – 9 – 10 – 6 hyb. recidiva with red buds × mut. recidiva – 51 – 4 – 17 – 15 – 19 – 5 – 7 – 2

**18.** Mut. recidiva – 28 × mut. simulans – 3 – 20 – 11 – 30 – 16 – 1 – 9 – 10 – 1 hyb. recidiva with red buds × mut. recidiva – 51 – 4 – 17 – 15 – 19 – 5 – 7 – 2

## TABLE II

ANALYSIS OF THE $P_1$, $P_2$ AND $P_3$ GENERATIONS OF *Oe. pratincola* mut. *recidiva*, WHICH AROSE AS A SECONDARY MUTATION, THROUGH MUT. *nummularia*, FROM STRAIN LEXINGTON I OF *Oe. pratincola*

The mutation occurred in open-pollinated seed

| Parent plant | Seeds planted | Germinations | Plants saved | Dead | *Pratincola* f. *typica* | Mut. *nummularia* | Mut. *tortuosa* | Mut. *gravida* | Mut. *recidiva* | Other forms |
|---|---|---|---|---|---|---|---|---|---|---|
| *Oe. pratincola* Lexington I | 635 | 268 | 268 | | 259 | 3 | 0 | 0 | 0 | 6 |
| I–13 *nummularia* | 190 | 23 | 23 | 4 | 0 | 18* | 1 | 0 | 0 | 0 |
| I–13–3 *nummularia* | 265 | 69 | 69 | 14 | 0 | 47 | 0 | 1 | 1 | 6† |

* One of these appeared to be a tetraploid plant.
† Of these 6 plants, 4 were mut. *graminea*, 1 mut. *gravida*, and 1 mut. *grisea*(?).

## TABLE III

ANALYSIS OF THE $F_1$ TO $F_9$ GENERATIONS, INCLUSIVE, OF *Oe. pratincola* mut. *recidiva*, WHICH AROSE AS A SECONDARY MUTATION, THROUGH MUT. *nummularia*, FROM STRAIN LEXINGTON I OF *Oe. pratincola*

The mutation occurred in open-pollinated seed

| Parent plant | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* | Gray runts | Other forms |
|---|---|---|---|---|---|---|---|
| $F_1$ GENERATION | | | | | | | |
| I–13–3–5 mut. *recidiva* | 2,281 | | 200 | 9 | 174 | 15‡ | 2§ |
| $F_2$ GENERATION | | | | | | | |
| I–13–3–5–51 | ca. 400 | 6 | 6 | 1 | 4 | | 1 |
| I–13–3–5–13 | ca. 1,200 | 56 | 56 | | 26 | 30 | |
| I–13–3–5–45 | ca. 1,400 | 44 | 42 | | 32* | 10 | |
| I–13–3–5–66 | ca. 1,400 | 75 | 75 | | 37* | 37 | 1* |
| I–13–3–5–29 | ca. 1,500 | 619 | 100 | | 45 | 55 | |
| I–13–3–5–22 | ca. 1,400 | 100 | 100 | | 24 | 76 | |
| I–13–3–5–25 | ca. 2,500 | 557 | 100 | | 30 | 68 | 2 |
| I–13–3–5–18 | ca. 1,150 | 550 | 300 | | 126* | 174 | |
| I–13–3–5–11 | ca. 1,100 | 298 | 100 | | 38 | 62 | |
| I–13–3–5–14 | ca. 1,100 | 19 | 19 | | 1 | 18 | |
| I–13–3–5–21 | ca. 1,100 | 19 | 19 | | 9 | 10 | |
| I–13–3–5–23 | ca. 800 | 4 | 4 | | 0 | 4 | |
| I–13–3–5–73 | ca. 1,100 | 18 | 18 | | 7* | 11 | |
| TOTAL | ca.16,150 | 2,365 | 939 | 1 | 379† | 556 | 4‖ |
| $F_3$ GENERATION | | | | | | | |
| I–13–3–5–51–3 | ca. 1,600 | 27 | 27 | 3 | 7 | 17 | |
| I–13–3–5–51–4 | ca. 1,700 | 343 | 150 | | 30 | 119 | 1 |
| I–13–3–5–51–5 | ca. 900 | 4 | 4 | 1 | 1 | 2 | |
| I–13–3–5–13–50 | ca. 1,300 | 697 | 25 | | 17 | 8 | |
| I–13–3–5–18–19 | ca. 1,800 | 1,330 | 25 | | 16 | 9 | |
| I–13–3–5–25–36 | ca. 1,500 | 1,134 | 25 | | 12 | 13 | |
| I–13–3–5–29–4 | ca. 1,200 | 686 | 25 | | some | some | |
| I–13–3–5–45–7 | ca. 850 | 382 | 25 | | 10 | 15 | |
| TOTAL | ca.10,850 | 4,603 | 306 | 4 | 93 | 183 | 1¶ |

* Like the parent plant, all plants of this culture lacked viscid pubescence.
† Eighteen plants of this group lacked viscid pubescence (in addition to the 195 from parents lacking viscid pubescence).
‡ This class was selected against in pricking off; there should have been more runts in the culture.
§ Of these two plants, one was mut. *fallax*, the other mut. *nitida*.
‖ Of these four plants, three were mut. *sublatifolia* and one mut. *graminea*-like.
¶ This plant was mut. *angustifolia*.

TABLE III (*continued*)

| Parent plant | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* | Gray runts | Other forms |
|---|---|---|---|---|---|---|---|
| $F_4$ Generation | | | | | | | |
| I–13–3–5–51–4 | | | | | | | |
| –17 | ca. 2,200 | 1,595 | 25 | | 11 | 14 | |
| I–13–3–5–25–36 | | | | | | | |
| –5 | 642 | 9 | 9 | | 4 | 5 | |
| Total | ca. 2,842 | 1,604 | 34 | | 15 | 19 | |
| $F_5$ Generation | | | | | | | |
| I–13–3–5–51– | | | | | | | |
| 4–17–15 | 883 | 21 | 21 | 12 | 6 | 3 | |
| $F_6$ Generation | | | | | | | |
| I–13–3–5–51–4 | | | | | | | |
| –17–15–19 | | ca. 175 | 25 | 11 | 3 | 11 | |
| $F_7$ Generation | | | | | | | |
| I–13–3–5–51– | | | | | | | |
| 4–17–15–19–5 | | 50 | 50 | | some | some | |
| $F_8$ Generation | | | | | | | |
| I–13–3–5–51– | | | | | | | |
| 4–17–15–19–5–7 | | ca.1525 | 25 | | 6 | 19 | |
| $F_9$ Generation | | | | | | | |
| I–13–3–5–51–4– | | | | | | | |
| 17–15–19–5–7–2 | | 25 | 25 | 6 | 14 | 5 | |
| I–13–3–5–51–4 | | | | | | | |
| –17–15–19–5–7 | | | | | | | |
| –23 | | ca. 250 | 50 | 8 | 10 | 32 | |
| Total | | ca. 275 | 75 | 14 | 24 | 37 | |

## TABLE IV

ANALYSIS OF THE $P_1$ GENERATION OF *Oe. pratincola* mut. *simulans*, WHICH AROSE IN THE $F_1$ GENERATION OF A CROSS WITHIN STRAIN LEXINGTON C OF *Oe. pratincola*

| Parent plant | Seeds planted | Germinations | Plants saved | Mut. *simulans* | Mut. *nitida* |
|---|---|---|---|---|---|
| C–22 f. *typica*–(15 mut. *nitida* × 10 f. *typica*) | 22 | 4 | 4 | 1 | 3 |

## TABLE V

ANALYSIS OF THE $F_1$ TO $F_{10}$ GENERATIONS, INCLUSIVE, OF *Oe. pratincola* mut. *simulans*, WHICH AROSE IN THE $F_1$ GENERATION OF A CROSS WITHIN STRAIN LEXINGTON C OF *Oe. pratincola*

| Parent plant | Seeds planted | Germinations | Plants saved | Mut. *simulans* | Other forms |
|---|---|---|---|---|---|
| $F_1$ GENERATION | | | | | |
| C–22–(15 × 10)–1 | 576 | 315 | 100 | 100 | |
| $F_2$ GENERATION | | | | | |
| C–22–(15 × 10)–1–25 | | | | | |
| C–22–(15 × 10)–1–24 | | | | | |
| C–22–(15 × 10)–1–3 | | | | | |
| $F_3$ GENERATION | | | | | |
| C–22–(15 × 10)–1–25–34 | 596 | 9 | 9 | 9 | |
| C–22–(15 × 10)–1–25–33 | 750 | 15 | 15 | 15 | |
| C–22–(15 × 10)–1–24–2 | 310 | 35 | 35 | 35 | |
| C–22–(15 × 10)–1–3–20 | 545 | 40 | 40 | 40 | |
| C–22–(15 × 10)–1–3–9 | 534 | 75 | 75 | 75 | |
| C–22–(15 × 10)–1–3–1 | 584 | 13 | 13 | 13 | |
| TOTAL | 3,319 | 187 | 187 | 187 | |
| $F_4$ GENERATION | | | | | |
| C–22–(15 × 10)–1–25–33–10 | ca. 800 | 313 | 25 | 25 | |
| C–22–(15 × 10)–1–25–34–1 | ca. 800 | 241 | 25 | all | |
| C–22–(15 × 10)–1–24–2–29 | ca. 1,150 | 197 | 40 | 38 | 2 |
| C–22–(15 × 10)–1–3–20–10 | ca. 1,150 | 200 | 25 | 25 | |
| C–22–(15 × 10)–1–3–20–11 | ca. 825 | ca. 205 | 25 | 25 | |
| TOTAL | ca. 4,725 | ca. 1,156 | 140 | 113+ | 2* |

* Of these two plants, one was mut. *rigida*-like, the other an unclassified dwarf.

TABLE V (*continued*)

| Parent plant | Seeds planted | Germinations | Plants saved | Mut. *simulans* | Other forms |
|---|---|---|---|---|---|
| $F_5$ Generation | | | | | |
| C–22–(15 × 10)–1–24–2–29–9 | ca. 500 | 268 | 25 | 25 | |
| C–22–(15 × 10)–1–3–20–10–22 | ca. 600 | 284 | 25 | 25 | |
| Total | ca. 1,100 | 552 | 50 | 50 | |
| $F_6$ Generation | | | | | |
| C–22–(15 × 10)–1–24–2–29–9–4 | 513 | 23 | 23 | 23 | |
| C–22–(15 × 10)–1–3–20–10–22–11 | 452 | 12 | 12 | 12 | |
| Total | 965 | 35 | 35 | 35 | |
| $F_7$ Generation | | | | | |
| C–22–(15 × 10)–1–24–2–29–9–4–19 | | 21 | 21 | 21 | |
| $F_8$ Generation | | | | | |
| C–22–(15 × 10)–1–24–2–29–9–4–19–5 | | 53 | 25 | 25 | |
| $F_9$ Generation | | | | | |
| C–22–(15 × 10)–1–24–2–29–9–4–19–5–16 | | ca. 525 | 25 | 25 | |
| $F_{10}$ Generation | | | | | |
| C–22–(15 × 10)–1–24–2–29–9–4–19–5–16–14 | | ca. 125 | 25 | 25 | |

## TABLE VI

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *recidiva* (GREEN BUDS) × MUT. *simulans* (RED BUDS)

Constitutions: recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green × simulans alpha ♀ red (and occasionally beta ♀ red); beta ♂ red (and occasionally alpha ♂ red) → rediciva alpha red beta red (hyb. *recidiva* with red buds); beta green beta red (beta-beta hybrid); and occasionally recidiva alpha red simulans alpha red (alpha-alpha hybrid) and beta green simulans alpha red (hyb. *simulans* with green buds)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds | Beta-beta hybrid | Hyb. *simulans* with green buds | Alpha-alpha hybrid | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,331 | 419 | 335 | 2 | 38 | 291 | 2 | | 2 |
| 2 | 184 | 36 | 36 | 1 | 3 | 32 | | | |
| 3 | 84 | 65 | 65 | | 7 | 55 | 2 | 1 | |
| 4 | 215 | 16 | 16 | | 2 | 14 | | | |
| 15 | | ca. 200 | 100 | 1 | 5 | 94 | | | |
| TOTAL | 1,814 + | ca. 736 | 552 | 4 | 55 | 486 | 4 | 1 | 2* |

* Of these two plants, one was mut. *sublatifolia* and the other mut. *ericacea*.

## TABLE VII

ANALYSIS OF THE $F_2$ TO $F_7$ GENERATIONS, INCLUSIVE, RESULTING FROM THE SELF-POLLINATION OF PLANTS OF HYB. *recidiva* WITH RED BUDS (RECIDIVA ALPHA RED BETA RED), CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE VI

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds | Runts (beta-beta) | Other forms |
|---|---|---|---|---|---|---|---|---|
| $F_2$ GENERATION | | | | | | | | |
| 1 | 40 | ca. 800 | 72 | 72 | 12 | 60 | | |
| 1 | 11 | ca. 1,000 | 48 | 47 | 5 | 39 | | 3 |
| 1 | 15 | ca. 900 | 28 | 27 | 5 | 22 | | |
| 1 | 53 | ca. 800 | 3 | 2 | 1 | 1 | | |
| 3 | 30 | ca. 1,350 | 33 | 25 | | 25 | | |
| 3 | 41 | ca. 700 | 55 | 25 | 9 | 16 | | |
| TOTAL | | ca. 5,550 | 239 | 198 | 32* | 163 | | 3† |
| $F_3$ GENERATION | | | | | | | | |
| 1 | 40–70 | ca. 900 | 13 | 12 | | 12 | | |
| 1 | 15–9 | ca. 1,000 | 25 | 23 | 3 | 20 | | |
| 1 | 11–7 | ca. 750 | 23 | 23 | 9 | 14 | | |
| 3 | 30–16 | ca. 323 | 13 | 13 | | 13 | | |
| TOTAL | | ca. 2,973 | 74 | 71 | 12* | 59 | | |
| $F_4$ GENERATION | | | | | | | | |
| 1 | 15–9–11 | 995 | 123 | 25 | 6 | 19 | | |
| 3 | 30–16–1 | | 20 | 20 | | 20 | | |
| TOTAL | | 995+ | 143 | 45 | 6* | 39 | | |
| $F_5$ GENERATION | | | | | | | | |
| 3 | 30–16–1 –9 | | 40 | 25 | | 24 | | 1 |
| $F_6$ GENERATION | | | | | | | | |
| 3 | 30–16–1 –9–10 | | ca. 225 | 25 | | 23 | 2 | |
| $F_7$ GENERATION | | | | | | | | |
| 3 | 30–16–1 –9–10–6 | | 21 | 21 | | 19 | | 2 |

* These plants were doubtless runts.
† These three plants were mut. *sublatifolia*.

## TABLE VIII

ANALYSIS OF THE $F_2$ AND $F_3$ GENERATIONS RESULTING FROM THE SELF-POLLINATION OF THE BETA-BETA HYBRIDS (BETA GREEN BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE VI

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Gray plants ranging from good beta-beta hybrids to runts |
|---|---|---|---|---|---|---|
| $F_2$ GENERATION | | | | | | |
| 1 | 1 | ca. 800 | 21 | 21 | | 21 |
| 1 | 10 | ca. 1,500 | 57 | 50 | | 50 |
| 1 | 9 | ca. 1,300 | 35 | 33 | | 33 |
| 1 | 7 | ca. 900 | 26 | 26 | | 26 |
| 1 | 86 | ca. 900 | 50 | 50 | | 50 |
| 1 | 81 | ca. 1,000 | 45 | 43 | | 43 |
| 1 | 48 | ca. 500 | 89 + | + | | all |
| 1 | 101 | ca. 900 | 127 + | + | | all |
| 1 | 39 | ca. 2,170 | 5 | 5 | 1 | 4 |
| 1 | 80 | ca. 1,400 | 14 | 13 | 4 | 9 |
| TOTAL | | ca. 11,370 | 469 + | 241 + | 5 | 236 + |
| $F_3$ GENERATION | | | | | | |
| 1 | 48–4 | ca. 3,200 | 2 | 2 | 1 | 1 |
| 1 | 10–6 | | 25 | 25 | 2 | 23 |
| 1 | 9–27 | ca. 2,400 | 5 | 5 | 1 | 4 |
| 1 | 48–2 | ca. 1,100 | 7 | 7 | 3 | 4 |
| 1 | 86–17 | ca. 1,350 | 13 | 13 | 8 | 5 |
| 1 | 1–19 | ca. 100 | 2 | 2 | 1 | 1 |
| 1 | 48–3 | ca. 900 | 15 | 15 | 5 | 10 |
| TOTAL | | ca. 9,050 + | 69 | 69 | 21 | 48 |

## TABLE IX

ANALYSIS OF THE $F_2$ AND $F_3$ GENERATIONS RESULTING FROM THE SELF-POLLINATION OF PLANTS OF HYB. *simulans* WITH GREEN BUDS (BETA GREEN SIMULANS ALPHA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE VI

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *simulans* with green buds | Other forms |
|---|---|---|---|---|---|---|---|
| $F_2$ GENERATION | | | | | | | |
| 1 | 19 | ca. 900 | 355 | 250 | 2 | 248* | |
| $F_3$ GENERATION | | | | | | | |
| 1 | 19–96 | ca. 900 | 298 | 25 | | 25 | |
| 1 | 19–106 | 658 | 74 | 25 | | 25 | |
| 1 | 19–39 | ca. 400 | 25 | 25 | | 24 | 1 |
| 1 | 19–62 | ca. 800 | 25 | 25 | | 25 | |
| 1 | 19–196 | ca. 750 | 32 | 25 | | 25 | |
| TOTAL | | ca. 3,508 | 454 | 125 | | 124† | 1‡ |

* 15 plants of this group lacked viscid pubescence.
† 4 plants of this group lacked viscid pubescence.
‡ This plant was mut. *ericacea*.

## TABLE X

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS) × MUT. *recidiva* (GREEN BUDS)

Constitutions: simulans alpha ♀ red (and occasionally beta ♀ red); beta ♂ red (and occasionally alpha ♂ red) × recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green → simulans alpha red beta green (hyb. *simulans* with green buds); simulans alpha red recidiva alpha red (alpha-alpha hybrid); and occasionally beta red recidiva alpha red (hyb. *recidiva* with red buds) and beta red beta green (beta-beta hybrid)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Hyb. *simulans* with green buds | Alpha-alpha hybrid | Hyb. *recidiva* with red buds | Beta-beta hybrid | Other forms |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 1,782 | 748 | 550 | 6 | 196 | 341 | 4 | 1 | 2 |
| 6 | 454 | 369 | 100 | 2 | 65 | 32 | 0 | 0 | 1 |
| 7 | 581 | 315 | 100 | 3 | 57 | 38 | 1 | 1 | 0 |
| 16 | | ca. 335 | 200 | 6 | 194 | 0 | 0 | 0 | 0 |
| TOTAL | 2,817 | ca. 1,767 | 950 | 17 | 512 | 411 | 5 | 2 | 3* |

* Of these 3 plants, 1 was mut. *sublatifolia* and two were not classified.

## TABLE XI

ANALYSIS OF THE $F_2$ TO $F_8$ GENERATIONS, INCLUSIVE, RESULTING FROM THE SELF-POLLINATION OF PLANTS OF HYB. *simulans* WITH GREEN BUDS (SIMULANS ALPHA RED BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION OF THE CROSS RECORDED IN TABLE X

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *simulans* with green buds | Dwarf mutations | Other forms |
|---|---|---|---|---|---|---|---|---|
| $F_2$ GENERATION | | | | | | | | |
| 5 | 30 | ca. 1,300 | 97 | 97 | 2 | 84 | 6 | 5 |
| 5 | 176 | ca. 1,100 | 210 | 200 | 6 | 188 | 6 | 0 |
| 5 | 18 | ca. 900 | 65 | 61 | 3 | 55 | 3 | 0 |
| 5 | 148 | ca. 700 | 70 | 70 | 1 | 66 | 3 | 0 |
| 5 | 112 | ca. 900 | 172 | 150 | 2 | 142 | 6 | 0 |
| TOTAL | | 4,900 | 614 | 578 | 14 | 535* | 24 | 5 |
| $F_3$ GENERATION | | | | | | | | |
| 5 | 30–76 | ca. 800 | 189 | 25 | | 25 | | |
| 5 | 176–173 | ca. 400 | 34 | 25 | | 24 | | 1 |
| 5 | 18–1 | ca. 850 | 23 | 23 | | 17 | 5 | 1 |
| 5 | 112–66 | ca. 300 | 250 | 25 | | 25 | | |
| 5 | 112–15 | ca. 1,100 | 564 | 25 | | 24 | | 1 |
| 5 | 18–17 | 945 | 122 | 25 | | 25 | | |
| 5 | 176–171 | ca. 600 | 21 | 21 | | 20 | | 1 |
| 5 | 30–49 | ca. 500 | 11 | 11 | | 11 | | |
| TOTAL | | ca. 5,495 | 1,214 | 180 | | 171† | 5 | 4 |
| $F_4$ GENERATION | | | | | | | | |
| 5 | 112–66–9 | 619 | 392 | 25 | | 25 | | |
| $F_5$ GENERATION | | | | | | | | |
| 5 | 112–66 –9–6 | | ca. 65 | 25 | 2 | 18‡ | | 5 |
| $F_6$ GENERATION | | | | | | | | |
| 5 | 112–66–9 –6–2 | | ca. 50 | 25 | | 23 | | 2 |
| $F_7$ GENERATION | | | | | | | | |
| 5 | 112–66–9 –6–2–8 | | ca. 825 | 25 | | 25 | | |
| $F_8$ GENERATION | | | | | | | | |
| 5 | 112–66–9 –6–2–8–7 | | ca. 525 | 25 | | 24 | | 1 |

* 42 plants of this group lacked viscid pubescence.
† 6 plants of this group lacked viscid pubescence.
‡ 1 plant of this group lacked viscid pubescence.
Of the 17 plants recorded under "other forms," 10 were mut. *fallax*-like, 2 mut. *debilis*-like, 1 mut. *grisella*, 1 a small plant of hyb. *simulans*, and 1 *pratincola* f. *typica* occurring as a weed.

## TABLE XII

ANALYSIS OF THE $F_2$ TO $F_8$ GENERATIONS, INCLUSIVE, RESULTING FROM THE SELF-POLLINATION OF ALPHA-ALPHA HYBRID (SIMULANS ALPHA RECIDIVA ALPHA) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION OF THE CROSS RECORDED IN TABLE X

| Key number | Parent plant | Seeds planted | Germinations | Seedlings | | | | Plants saved | Dead | Alpha-alpha hybrid | Other forms |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Normal | White | "Lethal" | Pale | | | | |
| $F_2$ GENERATION | | | | | | | | | | | |
| 5 | 157 | ca. 600 | ca. 180 | 48 | 43 | ca. 90 | | 48 | 12 | 36 | |
| 5 | 170 | ca. 600 | 58 | 7 | 31 | 6 | 14 | 7 | 2 | 5 | |
| 5 | 57 | ca. 550 | 68 | 12 | 12 | 44 | | 12 | 6 | 6 | |
| 5 | 174 | | 226 | 45 | 27 | 154 | | 43 | 19 | 24 | |
| 5 | 300 | ca. 750 | 45 | 2 | 9 | 34 | | 2 | 1 | 1 | |
| 5 | 165 | ca. 600 | 59 | 5 | 3 | 51 | | 5 | 3 | 2 | |
| 5 | 242 | ca. 900 | 33 | 3 | 9 | 18 | 3 | 3 | 3 | | |
| 5 | 39 | ca. 1,000 | 102 | 50 | 11 | 41 | | 50 | 13 | 37 | |
| 5 | 6 | ca. 850 | 73 | 6 | 6 | 61 | | 6 | 2 | 3 | 1 |
| 5 | 52 | ca. 900 | 24 | 4 | 1 | 19 | | 4 | 4 | | |
| | TOTAL | ca. 6,750+ | ca. 868 | 182 | 152 | ca. 518 | 17 | 180 | 65† | 114 | 1* |
| $F_3$ GENERATION | | | | | | | | | | | |
| 5 | 39–3 | ca. 1,400 | 118 | 15 | 25 | 78 | | 15 | 5 | 10 | |
| 5 | 174–37 | ca. 1,000 | 42 | 6 | 2 | 34 | | 6 | 4 | 2 | |
| | TOTAL | ca. 2,400 | 160 | 21 | 27 | 112 | | 21 | 9 | 12 | |
| $F_4$ GENERATION | | | | | | | | | | | |
| 5 | 39–3–8 | 796 | 361 | 203 | 62 | 96 | | 50 | | 50 | |
| $F_5$ GENERATION | | | | | | | | | | | |
| 5 | 39–3–8–6 | | 674 | 285 | 106 | 283 | | 25 | | 25 | |
| 5 | 39–3–8–11 | | ca. 195 | | | | | 50 | | 50 | |
| | TOTAL | | ca. 869 | 285+ | 106+ | 283+ | | 75 | | 75 | |
| $F_6$ GENERATION | | | | | | | | | | | |
| 5 | 39–3–8–6–9 | | ca. 325 | 75 | ca. 94 | ca. 150 | | 25 | | 25 | |
| $F_7$ GENERATION | | | | | | | | | | | |
| 5 | 39–3–8–6–9–11 | | ca. 550 | | | | | 50 | | 50 | |
| $F_8$ GENERATION | | | | | | | | | | | |
| 5 | 39–3–8–6–9–11–32 | | ca. 225 | | | | | 25 | | 25 | |
| 5 | 39–3–8–6–9–11–25 | | ca. 225 | | | | | 25 | | 25 | |
| | TOTAL | | ca. 450 | | | | | 50 | | 50 | |

* This plant was *Oe. pratincola* f. *typica* and was doubtless included in this culture by error.
† These plants probably lacked chlorophyll.

## TABLE XIII

Analysis of the $F_2$ generation resulting from the self-pollination of a plant of hyb. *recidiva* with red buds (beta red recidiva alpha red) of the $F_1$ generation of the cross recorded in Table X

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Hyb. *recidiva* with red buds | Runt |
|---|---|---|---|---|---|---|
| 7 | 85 | ca. 650 | 4 | 4 | 2 | 2 |

## TABLE XIV

Analysis of the $F_2$ generation resulting from the self-pollination of two plants of the beta-beta hybrid (beta red beta green) of the $F_1$ generation of the cross recorded in Table X

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Beta-beta hybrid | Runt |
|---|---|---|---|---|---|---|---|
| 7 | 93 | ca. 1,350 | 18 | 18 | 4 | 13 | 1 |
| 7 | 43 | ca. 2,000 | 31 | 25 | 7 | 12 | 6 |
| Total | | ca. 3,350 | 49 | 43 | 11 | 25 | 7 |

## TABLE XV

Analysis of the $F_1$ generation of the following cross: *Oe. pratincola* mut. *recidiva* (green buds) × beta-beta hybrid (green buds)

Constitutions: recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green × beta ♀ green and beta ♀ red; beta ♂ green and beta ♂ red → recidiva alpha red beta green (mut. *recidiva*); recidiva alpha red beta red ( hyb. *recidiva* with red buds); beta green beta green (runt); and beta green beta red (beta-beta hybrid)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* | Hyb. *recidiva* with red buds | Beta-beta hybrid | Small beta-beta hybrid and runt |
|---|---|---|---|---|---|---|---|---|
| 8 × 1–9 | 391 | 75 | 71 | 7 | 3 | 4 | 20 | 37 |
| 9 × 1–38 | 1,080 | 260 | 200 | 110 | 12* | 14 | 29 | 35 |
| 10 × 1–86–17–7 | 467 | 40 | 40 | 2 | | 2 | 6 | 30 |
| Total | 1,938 | 375 | 311 | 119 | 15 | 20 | 55 | 102 |

* One of these plants lacked viscid pubescence.

## TABLE XVI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A PLANT OF MUT. *recidiva* (RECIDIVA ALPHA RED BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XV

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Mut. *recidiva* |
|---|---|---|---|---|---|
| 9 × 1–38 | 10 | 499 | 22 | 22 | 22 |

## TABLE XVII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF THREE PLANTS OF HYB. *recidiva* WITH RED BUDS (RECIDIVA ALPHA RED BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XV

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds | Beta-beta hybrid |
|---|---|---|---|---|---|---|---|
| 8×1–9 | 3 | 680 | 3 | 3 | 2 | | 1 |
| 10×1–86–17–7 | 24 | | ca. 150 | 50 | | 49 | 1 |
| 9 × 1–38 | 52 | 584 | 20 | 20 | | 20 | |
| TOTAL | | 1,264+ | ca. 173 | 73 | 2 | 69 | 2 |

## TABLE XVIII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF TWO BETA-BETA HYBRIDS (BETA GREEN BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XV

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Gray plants ranging from good beta-beta hybrid to runt |
|---|---|---|---|---|---|---|
| 8 × 1–9 | 41 | ca. 1,600 | 277 | 50 | 15 | 35 |
| 8 × 1–9 | 9 | ca. 2,100 | 78 | 50 | 28 | 22 |
| TOTAL | | ca. 3,700 | 355 | 100 | 43 | 57 |

## TABLE XIX

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: BETA-BETA HYBRID (GREEN BUDS) × MUT. *recidiva* (GREEN BUDS)

Constitutions: beta ♀ green and beta ♀ red; beta ♂ green and beta ♂ red × recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green → beta green recidiva alpha red (mut. *recidiva*); beta red recidiva alpha red (hyb. *recidiva* with red buds); beta green beta green (runt); and beta red beta green (beta-beta hybrid)

| Key number | Seeds planted | Germination | Plants saved | Dead | Mut. *recidiva* | Hyb. *recidiva* with red buds | Gray plants ranging from good beta-beta hybrid to runt |
|---|---|---|---|---|---|---|---|
| 1–39 × 9 | 823 | 733 | 200 | 55 | 55 | 60 | 30 |
| 1–38 × 9 | 970 | 761 | 200 | 38 | 61 | 86 | 15 |
| 1–86–17–7 × 10 | 173 | 34 | 34 | 3 | 10 | 14 | 7 |
| TOTAL | 1,966 | 1,528 | 434 | 96 | 126* | 160† | 52 |

* Three plants of this group lacked viscid pubescence.
† Seven plants of this group lacked viscid pubescence.

## TABLE XX

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF TWO PLANTS OF MUT. *recidiva* (RECIDIVA ALPHA RED BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XIX

| Key number | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* | Runt |
|---|---|---|---|---|---|---|
| 1–39 × 9 | 650 | 39 | 25 | 13 | 12* | |
| 1–86–17–7 × 10 | | ca. 150 | 50 | | 46 | 4 |
| TOTAL | 650+ | ca. 189 | 75 | 13 | 58 | 4 |

* One of these plants lacked viscid pubescence.

## TABLE XXI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF THREE PLANTS OF HYB. *recidiva* WITH RED BUDS (RECIDIVA ALPHA RED BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XIX

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds | Runt | Other forms |
|---|---|---|---|---|---|---|---|---|
| 1–38 × 9 | 125 | 550 | 34 | 25 | | 25* | | |
| 1–39 × 9 | 8 | 483 | 60 | 25 | | 24 | | 1† |
| 1–86–17–7 × 10 | 6 | | ca. 150 | 50 | 5 | 12 | 33 | |
| TOTAL | | 1,033 + | ca. 244 | 100 | 5 | 61 | 33 | 1 |

* Two of these plants lacked viscid pubescence.
† This plant was mut. *sublatifolia*.

## TABLE XXII

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A BETA-BETA HYBRID PLANT (BETA RED BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XIX

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Beta-beta hybrid |
|---|---|---|---|---|---|
| 1–38 × 9 | 11 | ca. 1,200 | 100 | 25 | 25* |

* Most, but not all, of these plants were of full size.

## TABLE XXIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *recidiva* (GREEN BUDS) × HYB. *recidiva* WITH RED BUDS

Constitutions: recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green × recidiva alpha ♀ red and beta ♀ red; recidiva alpha ♂ red and beta ♂ red → recidiva alpha red beta red (hyb. *recidiva* with red buds); beta green recidiva alpha red (mut. *recidiva*); beta green beta red (beta-beta hybrid)

| Key number | Seeds planted | Germinations | Plants saved | Hyb. *recidiva* with red buds | Beta-beta hybrid |
|---|---|---|---|---|---|
| 8 × 1–5 | ca. 150 | 2 | 2 | 1 | 1 |

## TABLE XXIV

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A BETA-BETA HYBRID (BETA GREEN BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXIII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Beta-beta hybrid |
|---|---|---|---|---|---|---|
| 8 × 1–5 | 2 | ca. 1,600 | 10 | 10 | 2 | 8* |

* These plants varied in size and imperfection.

## TABLE XXV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *recidiva* WITH RED BUDS × MUT. *recidiva* (GREEN BUDS)

Constitutions: recidiva alpha ♀ red and beta ♀ red; recidiva alpha ♂ red and beta ♂ red × recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green → recidiva alpha red beta green (mut. *recidiva*); beta red recidiva alpha red (hyb. *recidiva* with red buds); and beta red beta green (beta-beta hybrid)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *recidiva* | Hyb. *recidiva* with red buds | Beta-beta hybrid |
|---|---|---|---|---|---|---|
| 1–15 × 8 | 5 | 3 | 3 | 1 | 2 | |
| 17 | | 15 | 15 | 7 | | 8 |
| 18 | | 25 | 25 | 18 | | 7 |
| TOTAL | | 43 | 43 | 26 | 2 | 15 |

## TABLE XXVI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A PLANT OF HYB. *recidiva* WITH RED BUDS (RECIDIVA ALPHA RED BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXV

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds |
|---|---|---|---|---|---|---|
| 1–15 × 8 | 3 | 1,071 | 3 | 3 | 2 | 1 |

## TABLE XXVII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *recidiva* (GREEN BUDS) × HYB. *simulans* WITH GREEN BUDS

Constitutions: recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green × simulans alpha ♀ red; beta ♂ green → recidiva alpha red beta green (mut. *recidiva*); and beta green beta green (runt)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *recidiva* | Runt | Hyb. *simulans* with green buds |
|---|---|---|---|---|---|---|
| 8 × 5–176 | 126 | 55 | 53 | 4 | 47 | 2* |

* These two plants give evidence that simulans alpha can function as a sperm in competition with beta of mut. *recidiva*.

## TABLE XXVIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS × MUT. *recidiva* (GREEN BUDS)

Constitutions: simulans alpha ♀ red; beta ♂ green × recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green → simulans alpha red recidiva alpha red (alpha-alpha hybrid); and simulans alpha red beta green (hyb. *simulans* with green buds)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Hyb. *simulans* with green buds | Alpha-alpha hybrid | Mut. *fallax*-like |
|---|---|---|---|---|---|---|---|
| 5–178 × 8 | 439 | 79 | 79 | 1 | 48 | 29 | 1 |

## TABLE XXIX

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A PLANT OF HYB. *simulans* WITH GREEN BUDS (SIMULANS ALPHA RED BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXVIII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Hyb. *simulans* with green buds | Mut. *fallax*-like |
|---|---|---|---|---|---|---|
| 5–176 × 8 | 34 | 581 | 10 | 10 | 7 | 3 |

## TABLE XXX

Analysis of the $F_1$ generation of the following cross: *Oe. pratincola* mut. *recidiva* (green buds) × alpha-alpha hybrid

Constitutions: recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green × simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red → beta green recidiva alpha red (mut. *recidiva*)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *recidiva* |
|---|---|---|---|---|
| 11 × 5–52 | 128 | 41 | 41 | 41 |

## TABLE XXXI

Analysis of the $F_2$ generation resulting from the self-pollination of two plants of mut. *recidiva* (recidiva alpha red beta green) chosen at random from the $F_1$ generation recorded in Table XXX

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* | Runt |
|---|---|---|---|---|---|---|---|
| 11 × 5–52 | 1 | 1,145 | 25 | 24 | 16* | 8 | |
| 11 × 5–52 | 23 | 1,540 | 50 | 50 | 30* | 18† | 2 |
| Total | | 2,685 | 75 | 74 | 46 | 26 | 2 |

* These plants were probably all runts.
† One of this group lacked viscid pubescence.

## TABLE XXXII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: ALPHA-ALPHA HYBRID × MUT. *recidiva* (GREEN BUDS)

Constitutions: simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red × recidiva alpha ♀ red and beta ♀ green; recidiva alpha ♂ red and beta ♂ green → simulans alpha red recidiva alpha red (alpha-alpha hybrid); simulans alpha red beta green (hyb. *simulans* with green buds); recidiva alpha red beta green (mut. *recidiva*)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* | Hyb. *simulans* with green buds | Alpha-alpha hybrid |
|---|---|---|---|---|---|---|---|
| 5–52 × 8 | 150 | 16 | 15 | 3 | | 7 | 5 |
| 12 | 92 | 50 | 50 | 3 | 2 | 41 | 4 |
| TOTAL | 242 | 66 | 65 | 6 | 2 | 48 | 9 |

## TABLE XXXIII

ANALYSIS OF THE $F_2$ AND $F_3$ GENERATIONS RESULTING FROM THE SELF-POLLINATION OF PLANTS OF HYB. *simulans* WITH GREEN BUDS (SIMULANS ALPHA GREEN BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXXII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *simulans* with green buds | Mut. *fallax* |
|---|---|---|---|---|---|---|---|
| $F_2$ GENERATION | | | | | | | |
| 12 | 47 | 1,004 | 38 | 37 | 1 | 31* | 5 |
| 5–52 × 8 | 3 | 880 | 15 | 15 | 1 | 9* | 5 |
| 5–52 × 8 | 11 | 756 | 15 | 15 | | 13 | 2 |
| 12 | 3 | 820 | 12 | 12 | | 8 | 4 |
| 12 | 7 | 173 | 6 | 6 | | 6* | |
| TOTAL | | 3,633 | 86 | 85 | 2 | 67 | 16 |
| $F_3$ GENERATION | | | | | | | |
| 12 | 3–3 | 735 | 321 | 50 | | 50 | |

* One of this group lacked viscid pubescence.

## TABLE XXXIV

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF TWO PLANTS OF ALPHA-ALPHA HYBRID (SIMULANS ALPHA RED RECIDIVA ALPHA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XXXII

| Key number | Parent plant | Seeds planted | Germinations | Seedlings | | | Plants saved | Dead | Alpha-alpha hybrid |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Normal | White | Lethal | | | |
| 5–52 × 8 | 1 | | 1 | 1 | | | 1 | | 1 |
| 5–52 × 8 | 9 | 477 | 47 | 25 | 4 | 18 | 25 | 14 | 11 |
| TOTAL | | 477+ | 48 | 26 | 4 | 18 | 26 | 14 | 12 |

## TABLE XXXV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: ALPHA-ALPHA HYBRID × MUT. *simulans* (RED BUDS)

Constitutions: simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red × simulans alpha ♀ red; beta ♂ red → simulans alpha red beta red (mut. *simulans*) and recidiva alpha red beta red (hyb. *recidiva* with red buds)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *simulans* |
|---|---|---|---|---|
| 5–6 × 13 | 26 | 11 | 11 | 11 |

## TABLE XXXVI

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS) × HYB. *simulans* WITH GREEN BUDS.

Constitutions: simulans alpha ♀ red; beta ♂ red × simulans alpha ♀ red; beta ♂ green → simulans alpha red beta green (hyb. *simulans* with green buds)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Hyb. *simulans* with green buds | Beta-beta hybrid |
|---|---|---|---|---|---|---|
| 13 × 5–176 | ca. 364 | 159 | 158 | 4 | 144 | 10 |

## TABLE XXXVII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS) × BETA-BETA HYBRID

Constitutions: simulans alpha ♀ red; beta ♂ red × beta ♀ green and beta ♀ red; beta ♂ green and beta ♂ red → simulans alpha red beta green (hyb. *simulans* with green buds) and simulans alpha red beta red (mut. *simulans*)

| Key number | Seeds planted | Germinations | Plants saved | Hyb. *simulans* with green buds | Mut. *simulans* |
|---|---|---|---|---|---|
| 13 × 1–1 | 308 | 12 | 12 | 11 | 1 |

## TABLE XXXVIII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* mut. *simulans* (RED BUDS) × HYB. *recidiva* WITH RED BUDS

Constitutions: simulans alpha ♀ red; beta ♂ red × recidiva alpha ♀ red and beta ♀ red; recidiva alpha ♂ red and beta ♂ red → simulans alpha red recidiva alpha red (alpha-alpha hybrid) and simulans alpha red beta red (mut. *simulans*)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Mut. *simulans* | Alpha-alpha hybrid |
|---|---|---|---|---|---|---|
| 13 × 1–11 | 81 | 65 | 58 | 1 | 35 | 22 |

## TABLE XXXIX

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: BETA-BETA HYBRID × HYB. *recidiva* WITH RED BUDS

Constitutions: beta ♀ green and beta ♀ red; beta ♂ green and beta ♂ red × recidiva alpha ♀ red and beta ♀ red; recidiva alpha ♂ red and beta ♂ red → beta green recidiva alpha red (mut. *recidiva*); beta red recidiva alpha red (hyb. *recidiva* with red buds); beta green beta red (beta-beta hybrid); and beta red beta red (runt)

| Key number | Seeds planted | Germinations | Plants saved | Mut. *recidiva* | Hyb. *recidiva* with red buds |
|---|---|---|---|---|---|
| 1–86–17–7 × 3–30–16 | 177 | 5 | 5 | 2 | 3 |

## TABLE XL

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *recidiva* WITH RED BUDS × ALPHA-ALPHA HYBRID

Constitutions: recidiva alpha ♀ red and beta ♀ red; recidiva alpha ♂ red and beta ♂ red × simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red → beta red recidiva alpha red (hyb. *recidiva* with red buds)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds | Other forms |
|---|---|---|---|---|---|---|
| 1–11 × 5–6 | 195 | 30 | 30 | 1 | 28 | 1* |

* This plant was mut. *sublatifolia.*

## TABLE XLI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF TWO PLANTS OF HYB. *recidiva* WITH RED BUDS (RECIDIVA ALPHA RED BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XL

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Hyb. *recidiva* with red buds |
|---|---|---|---|---|---|---|
| 1–11 × 5–6 | 14 | 773 | 5 | 4 | 4 | |
| 1–11 × 5–6 | 2 | 555 | 3 | 3 | 2 | 1 |
| TOTAL | | 1,138 | 8 | 7 | 6 | 1 |

## TABLE XLII

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: ALPHA-ALPHA HYBRID × HYB. *recidiva* WITH RED BUDS

Constitutions: simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red × recidiva alpha ♀ red and beta ♀ red; recidiva alpha ♂ red and beta ♂ red → simulans alpha red recidiva alpha red (alpha-alpha hybrid); simulans alpha red beta red (mut. *simulans*); recidiva alpha red beta red (hyb. *recidiva* with red buds)

| Key number | Seeds planted | Germinations | Plants saved | Dead | Alpha-alpha hybrid | Mut. *simulans* | Hyb. *recidiva* with red buds | Other forms |
|---|---|---|---|---|---|---|---|---|
| 14 | 140 | 39 | 39 | 20 | 14 | 3 | 1 | 1* |

* This plant was mut. *sublatifolia.*

## TABLE XLIII

ANALYSIS OF THE $F_2$ AND $F_3$ GENERATIONS RESULTING FROM THE SELF-POLLINATION OF A PLANT OF MUT. *simulans* (SIMULANS ALPHA RED BETA RED) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XLII

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Mut. *simulans* | Other forms |
|---|---|---|---|---|---|---|
| $F_2$ GENERATION | | | | | | |
| 14 | 20 | 723 | 5 | 5 | 5 | |
| $F_3$ GENERATION | | | | | | |
| 14 | 20–2 | 831 | 96 | 50 | 47 | 3* |

* Two of these were small mut. *albida*-like plants, and one was a narrow-leaved mut. *nitida*.

## TABLE XLIV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: *Oe. pratincola* hyb. *simulans* WITH GREEN BUDS × ALPHA-ALPHA HYBRID

Constitutions: simulans alpha ♀ red; beta ♂ green × simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red → simulans alpha red recidiva alpha red (alpha-alpha hybrid)

| Key number | Seeds planted | Germinations | Seedlings | | | Plants saved | Dead | Alpha-alpha hybrid |
|---|---|---|---|---|---|---|---|---|
| | | | Normal | White | Lethal | | | |
| 5–176 × 5–52 | 74 | 17 | 3 | 7 | 7 | 3 | 1 | 2 |

## TABLE XLV

ANALYSIS OF THE $F_1$ GENERATION OF THE FOLLOWING CROSS: ALPHA-ALPHA HYBRID × HYB. *simulans* WITH GREEN BUDS

Constitutions: simulans alpha ♀ red and recidiva alpha ♀ red; recidiva alpha ♂ red × simulans alpha ♀ red; beta ♂ green → simulans alpha red beta green (hyb. *simulans* with green buds) and recidiva alpha red beta green (mut. *recidiva*)

| Key number | Seeds planted | Germinations | Plants saved | Hyb. *simulans* with green buds | Mut. *recidiva* |
|---|---|---|---|---|---|
| 5–52 × 5–176 | 229 | 9 | 9 | 6 | 3 |

## TABLE XLVI

ANALYSIS OF THE $F_2$ GENERATION RESULTING FROM THE SELF-POLLINATION OF A PLANT OF MUT. *recidiva* (RECIDIVA ALPHA RED BETA GREEN) CHOSEN AT RANDOM FROM THE $F_1$ GENERATION RECORDED IN TABLE XLV

| Key number | Parent plant | Seeds planted | Germinations | Plants saved | Dead | Mut. *recidiva* |
|---|---|---|---|---|---|---|
| 5–52 × 5–176 | 6 | 622 | 8 | 8 | 7* | 1 |

* These plants were probably runts.

## TABLE XLVII

### Summary of Tables II–XLVI

This summary records $F_1$ progenies, and shows the few cases of departure from expectation in the cultures from which were derived the survival values of the various gametes given in the text (see page 149). Crosses (×) indicate that the type is expected, and naughts (0) that it is not. Bold-faced type indicates a departure from expectation, in the omission of an expected type. These omissions are discussed in the notes below the tables in which they occur, and it will be seen that none of them carry weight against the hypothesis of the survival values. Parentheses indicate that a type is metaclinic, resulting from the occasional functioning of a beta egg or an alpha sperm in mut. *simulans*

| Number of Table | Cross | Mut. *recidiva* | Mut. *simulans* | Hyb. *recidiva* with red buds | Hyb. *simulans* with green buds | Beta-beta hybrid | Runt | Alpha-alpha hybrid |
|---|---|---|---|---|---|---|---|---|
| VI | mut. *recidiva* × mut. *simulans* | 0 | 0 | × | (×) | × | 0 | (×) |
| X | mut. *simulans* × mut. *recidiva* | 0 | 0 | (×) | × | (×) | 0 | × |
| XV | mut. *recidiva* × beta-beta hyb. | × | 0 | × | 0 | × | × | 0 |
| XIX | beta-beta hyb. × mut. *recidiva* | × | 0 | × | 0 | × | × | 0 |
| XXIII | mut. *recidiva* × hyb. *recidiva* | **X*** | 0 | × | 0 | × | 0 | 0 |
| XXV | hyb. *recidiva* × mut. *recidiva* | × | 0 | × | 0 | × | 0 | 0 |
| XXVII | mut. *recidiva* × hyb. *simulans* | × | 0 | 0 | × | 0 | × | **X**† |
| XXVIII | hyb. *simulans* × mut. *recidiva* | 0 | 0 | 0 | × | 0 | 0 | × |

* See pages 144 and 150. † See page 150.

TABLE XLVII (*continued*)

| Number of Table | Cross | Mut. *recidiva* | Mut. *simulans* | Hyb. *recidiva* with red buds | Hyb. *simulans* with green buds | Beta-beta hybrid | Runt | Alpha-alpha hybrid |
|---|---|---|---|---|---|---|---|---|
| XXX | mut *recidiva* × alpha-alpha hyb. | × | 0 | 0 | 0 | 0 | 0 | 0 |
| XXXII | alpha-alpha hyb. × mut. *recidiva* | × | 0 | 0 | × | 0 | 0 | × |
| XXXV | alpha-alpha hyb. × mut. *simulans* | 0 | × | **X**‡ | 0 | 0 | 0 | 0 |
| XXXVI | mut. *simulans* × hyb. *simulans* | 0 | 0 | 0 | × | (×) | 0 | 0 |
| XXXVII | mut *simulans* × beta-beta hyb. | 0 | × | 0 | × | 0 | 0 | 0 |
| XXXVIII | mut. *simulans* × hyb. *recidiva* | 0 | × | 0 | 0 | 0 | 0 | × |
| XXXIX | beta-beta hyb. × hyb. *recidiva* | × | 0 | × | 0 | **X**§ | **X**§ | 0 |
| XL | hyb. *recidiva* × alpha-alpha hyb. | 0 | 0 | × | 0 | 0 | 0 | 0 |
| XLII | alpha-alpha hyb. × hyb. *recidiva* | 0 | × | × | 0 | 0 | 0 | × |
| XLIV | hyb. *simulans* × alpha-alpha hyb. | 0 | 0 | 0 | 0 | 0 | 0 | × |
| XLV | alpha-alpha hyb. × hyb. *simulans* | × | 0 | 0 | × | 0 | 0 | (**X**)† |

† See pages 145 and 150. ‡ See pages 143 and 149. § See pages 144 and 150.

# THE NUTRITIVE VALUE OF THE MUNG BEAN

HOWARD H. M. BOWMAN AND MARTIN A. YEE

THE mung bean, *Phaseolus aureus*, is one of five species common in the Oriental countries. These five species have already been referred to in a previous paper (1). They are *Phaseolus aureus*, *P. mungo*, *P. aconitifolius*, *P. angularis* and *P. calcaratus*, or the mung, urd, moth, adsuki and rice beans, respectively. All are closely related and resemble in habit our common Strophostyles or wild beans along the Atlantic Coast region. The mung bean is a very important item of food in China, India, and the other Eastern countries; it had been introduced into the United States prior to 1835 as a forage plant for cattle and as a green manure. It has been grown continuously in limited amounts in the southern states for the latter purpose, but Piper and Morse (2) in a Bulletin of the Department of Agriculture quote an article mentioning the use of the seeds as food. It has been cultivated in this country under the name of Oregon or Chickasaw pea. The plants attain a height of two to three feet and are bushy in habit. The blossoms, which are small and yellow, are borne in clusters. The pods likewise are clustered and are slender and long. The seeds are a rather dark-olive green and in some varieties are brown with all intervening shades. Possibly the most extensive use in this country of the mung bean as food for man is in the Chinese restaurants. These restaurants, which import tons of the beans annually, use them in the sprouted condition in the vegetable combinations of their menus. (See Pl. VII, Fig. 1.)

Since they are so largely used by the Chinese and other Oriental peoples as food, and since the authors had made vitamin studies of them in another paper, they were led to investigate

more thoroughly their actual content in the hope that the beans might be more generally used if they are proved to be especially rich in nutrients and accessories. A comparative study of the literature on the nutrients of other legumes of the bean group was attempted to learn whether the mung bean has any real claim to distinction in this connection. The studies of the nutritive value of the soy bean by Osborne and Mendel (3) and by Daniels and Nichols (4) show that the available protein of these beans is adequate for nutrition when the deficit in inorganic salts is made up and a little fat and carbohydrates are added to give sufficient balance. McCollum and Simmonds (5) in their studies likewise showed that in seed diets the most vital deficiencies are mineral salts, especially calcium and sodium. Several of these investigators also stated that beans were rather low in the content of several important nutrients, notably protein (except the soy bean).

Accordingly, then, chemical analyses of the mung bean were made and compared with those for other beans. The following table is a comparison of the analysis of the mung bean made by Church and quoted by Piper and Morse and the analysis made by Yee in the present work:

CHEMICAL CONTENTS OF THE MUNG BEAN

| | Yee | Church |
|---|---|---|
| Protein | 24.76 | 23.8 |
| Sugar and starches | 50.41 | 50.6 |
| Cellulose | 4.19 | 4.2 |
| Fats | 1.5 | 2.0 |
| Salts | 3.8 | 3.8 |
| Water | 11.5 | 11.4 |

The next table, which shows the contents of the mung bean, represents only the bulked averages of the various nutrients and constituents. Individual samples of these beans vary with the locality from which they are secured.

CHEMICAL ANALYSES OF VARIOUS KINDS OF BEANS

| | Protein | Sugar and starches | Cellulose | Fats | Salts | Water |
|---|---|---|---|---|---|---|
| Mung bean | 24.76 | 50.41 | 4.19 | 1.5 | 3.8 | 11.5 |
| Navy bean | 19.63 | 56.94 | 3.54 | 1.67 | 3.29 | 15.25 |
| Lima bean | 18.1 | 65.9 | | 1.5 | 4.1 | 10.4 |
| Frijoles | 21.9 | 65.1 | | 1.3 | 4.2 | 7.5 |
| Soy bean | 41.1 | 29.5 | 3.3 | 16.5 | 6.9 | 5.4 |

A more careful scrutiny of the amounts of the carbohydrates reveals variations in nutrients and shows that they compare with Daniels and Nichols for the soy bean as follows:

CARBOHYDRATES OF THE SOY AND MUNG BEANS

| | Soy bean (Daniels and Nichols) | Mung bean (Yee) |
|---|---|---|
| Starch | 0.5 | 2.26 |
| Dextrin | 3.1 | 6.49 |
| Pentosan | 4.9 | 5.34 |
| Galactin | 4.9 | |
| Cellulose | 3.3 | 4.19 |
| Organic acids | 1.4 | 1.69 |
| Sucrose | | 0.90 |

Concerning the carbohydrates it is noted that the starch present in the mung bean is considerably higher than in the soy bean and the sucrose is very low, whereas the estimate of digestible carbohydrates of Daniels and Nichols is twelve per cent for the soy bean, but only a trace of this is starch.

A comparison of the inorganic salts is shown in the following table, assembled from many sources:

PERCENTAGES OF INORGANIC CONTENTS OF VARIOUS BEANS

| Elements | Mung bean (Yee) | Soy bean (Mendel and Osborne) | Navy bean (Konig, Leach, 6, p. 310) |
|---|---|---|---|
| Ash in dry substance | 3.80 | 5.43 | 3.57 |
| Potassium | 16.3 | 2.06 | 42.49 |
| Sodium | 3.30 | 0.14 | 1.34 |
| Calcium | 16.15 | 0.18 | 4.74 |
| Magnesium | 4.45 | 0.30 | 7.08 |
| Iron | 4.80* | | 0.399 |
| Phosphorus | 6.77 | 0.82 | 12.25 |
| Sulfur | 0.413 | | 0.81 |
| Chlorine | | 0.005 | 1.57 |
| Silicon | 0.736 | | 0.343 |

* Ferric and aluminium oxides

A comparative examination of these three analyses of inorganic elements in beans shows that the mung bean's content of mineral salts is higher than that of the soy bean, although the latter has been found to have a high percentage of available protein so as to be considered a good food for human beings, except that its low percentage of mineral salts must be made up (Mendel and Osborne). The experiments by the writers on animal-feeding would indicate that the mung bean has sufficient of these salts to constitute a good food, since no ill effects due to deficiency of salts were noted.

The following work was done to determine by animal-feeding experiments the actual nutritive value of the mung bean. Six guinea pigs were selected from a young litter, all of them being approximately of the same weight. In the accompanying chart (Fig. 1) these weights are all reduced to zero so as to keep a uniformity in the growth-curves during the experiment, and only the gain in weight is used in making the comparisons, the ordinates being grams and the abscissae being weeks.

The six animals were placed in pairs in three hutches and fed on different diets. Those in Hutch No. 1 were on a diet composed of mung beans, 80 per cent; starch, 5 per cent; salts, 7 per cent; cod-liver oil and butter, 7 per cent; potato juice, 1

per cent. In this diet no protein was given except that in the mung beans, the purpose being to see if the young guinea pigs would thrive on the amount of native protein contained in the mung beans.

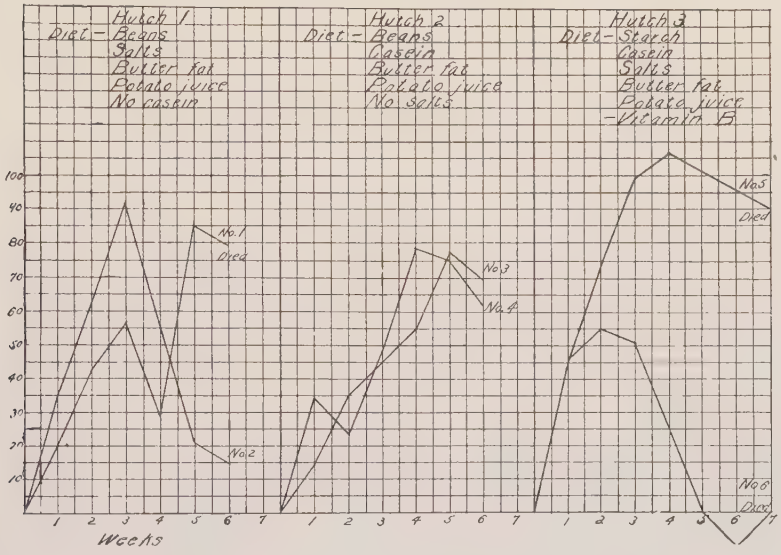


Fig. 1. Chart showing nutritive value of the mung bean

The animals in Hutch No. 2 were placed on a diet composed of mung beans, 67 per cent; casein, 20 per cent; cod-liver oil and butter, 7 per cent; starch, 5 per cent; potato juice, 1 per cent. In this case the addition of refined casein made up a deficiency of proteins in the mung beans, but the lack of mineral salts would tend to show whether or not the mung beans contained enough of these salts to produce normal growth in the animals, as McCollum, Mendel and others found this to be the case for navy and other beans.

The diet of the guinea pigs in Hutch No. 3 was made up of starch, 60 per cent; casein, 20 per cent; salts, 5 per cent; butter fat, 14 per cent; potato juice, 1 per cent. The element lacking here is Vitamin B, which occurs in the mung bean. In all three sets of diets the potato juice was added to furnish

Vitamin C and the butter fat and the cod-liver oil to furnish Vitamin A and Vitamin D, respectively.

The animals of Hutch No. 1, i.e., guinea pigs Nos. 1 and 2, attained only a maximum weight of about 95 grams, and after three weeks started to decline sharply, showing clearly the effect of the insufficient protein in the mung beans. Thus in this respect the results of the present investigators agree with those of other workers on other species of beans.

Animals Nos. 3 and 4, i.e., those in Hutch No. 2, kept increasing in weight until the fifth week, and then started to show only a slight decrease in weight. With regard to the mineral salts in the mung bean, it would seem from these results that there is a larger salt content in them than in most other species of beans or at least a larger supply of available salts, so that the dietary deficiency is not so quickly indicated. Possibly a longer time would have showed even a more favorable curve for the mung bean.

Animals Nos. 5 and 6 were placed on diets lacking Vitamin B, but corrected for lack of anti-scorbutic accessory. Early in the experiment, between the second and third weeks, they began to decline, thus showing the necessity of Vitamin B in diets of young animals so that growth can be maintained. When this decline was noted, which had already been observed in vitamin work of the present workers with pigeons, etc., Animal No. 5 was injected twice with small doses (one fourth of a milligram) of the solution of some of the crystals secured from the mung beans and assumed to be Vitamin B (see Pl. VII, Fig. 2). These two injections had the expected result of increasing the weight of the animal to over 100 grams. After the last injection a slight drop in weight was noted and shortly thereafter, in the sixth week, the animal died of an infection caused by being bitten on the foot.

## SUMMARY

These charts of a few simple animal experiments seem to indicate that the mung bean, in common with almost all beans, with the possible exception of the soy bean, is deficient in protein

when used as animal food. With regard to the mineral salts, the mung bean is perhaps superior to most beans, including the soy bean, in furnishing a fairly large amount to the diet. In Vitamin B the mung bean is known to be rich, as is indicated by the rapid death of animal No. 6 and the continued growth of his hutch mate when injected with the crystalline extract of these beans.

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PLATE VII

FIG. 1. Cluster of Mature Pods and Leaf of the Mung Bean (*Phaseolus aureus*)
(Courtesy of the United States Department of Agriculture)

FIG. 2. Crystals of Vitamin B extracted from the Mung Bean

# ACHROMATIC VARIATIONS IN PATHOGENIC FUNGI

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FOR many years the development of white tufts of mycelium had been noticed in presumably single-spore pure cultures of fungi. When bits of this white growth were by chance included in the inoculum, it was observed that the white tufts led to the development of white sectors in the cultures. In addition, gradual loss of the power of spore production was a common occurrence with cultures maintained in the laboratory for a long period as stock cultures.

Our attention was focused on this aberrant behavior by the experiences with cultures of *Phoma apiicola* Kleb. in a study of a celery disease begun by one of us (9) and continued by C. W. Bennett (1, 2) of the Department of Botany, Michigan State College. *Phoma apiicola* had been isolated and its pathogenicity to celery definitely shown. A culture was obtained from the International Institute for Pure Cultures and this by comparison cultures and by inoculations seemed to be identical with the American isolation. Work on the celery root rot was interrupted by the war and it was found by Mr. Bennett on his return that the stock cultures had lost color and were completely avirulent. Fresh isolations from diseased material were normal in behavior and of the same color as the early isolations. From the new isolations it was possible occasionally to pick sterile clumps of mycelium and to obtain gray or white forms which apparently had lost virulence and power of spore production.

This work, done with single-spore cultures of a fungus in which the sexual stage was not a factor, brought up many questions as to the proper interpretation of the phenomenon.

Since other cultures in the laboratory, more adaptable to culture tests, showed the same tendency, these have been used in an attempt to throw light upon the problem and to allow us to decide whether these variant forms were mutants, environmental modifications or sterile mycelium which, affected by conditions of long culture, needed special methods for rejuvenation.

## METHODS

The following cultures known to give rise to these aberrant forms were chosen for intensive study: *Sphaeropsis malorum* Pk. (Mich. Exp. Sta., No. 125); *Colletotrichum lindemuthianum* (Sacc. and Magn.) Br. and Cav. (Strains I and II); *Cladosporium fulvum* Cke.; *Septoria apii* Chester (freshly isolated).

Although the parent strains named above were progenies of presumably single-spore isolations, that is, isolation (from plates) of growths apparently from one spore, in order to make sure that only single-spore cultures were used in these experiments plates were poured by the ordinary dilution method and very dilute, well-shaken, suspensions of spores in corn meal agar were used. As soon as a well-isolated spore was found to have germinated — usually on the second day — its location in the plate was marked by an ink dot and the agar lying over the dot was scooped out with a flattened, sterile platinum needle. The agar containing the germinating spore was placed on a sterile slide and carefully examined under the high power of the microscope to make sure that only a single spore had been removed from the plate. This requirement once satisfied, the piece of agar containing the spore was again placed on a corn meal agar slant and allowed to grow. In more than twenty such plantings made by this method, there were but few spores that did not grow; none were found to have been contaminated by bacteria or fungi in the process of examination or transfer.

In this way single-spore cultures of the organisms named were obtained. All work subsequently to be reported was done with

these tested isolations. The media used were the standard sorts as well as certain synthetic solutions as indicated in the footnote on page 195. The chemicals used were Baker's analyzed and the glassware, except culture tubes and preparation dishes, was either Pyrex or Jena. All glass culture dishes were cleaned by immersing over night in cleaning solution followed by four rinsings in tap water and one rinsing in distilled water. The water used was distilled water which had been redistilled in a block tin still or in special cases (pH experiments) in a Jena glass still.

### TESTS ON LABORATORY MEDIA

*Septoria apii*

Six single-spore isolations were made on oat meal agar and transferred to corn meal agar, prune juice agar, synthetic medium No. 2 (see note on page 195), carrot plugs and corn meal. The organism grew normally upon all these media for a week, forming a black dense growth with numerous pycnidia scattered on the surface of the medium. Ten days after inoculation a white tuft was found in Isolation 5 (corn meal), forming a striking contrast with the normal black growth (Plate VIII, Fig. 1). Attempts were made to transfer bits of this white mycelium to Richards' solution, oat meal agar and corn meal, but it invariably produced a jet black growth in the new culture medium.

The same strain gave a second white tuft in a culture on prune juice agar. The white tuft transferred to synthetic medium No. 2 gave a black growth, apparently normal. Isolations 1 and 2 behaved in a similar way. Still another isolation developed "white islands" on oat meal agar and synthetic solution No. 2, but grew normally on being transferred.

*Sphaeropsis malorum*

This culture, which had been in stock for a long time, had presented some difficulties in securing single-spore strains because of the absence of pycnidia. On being grown on Coons' synthetic liquid medium it sporulated abundantly and two single-spore isolations were obtained. These when grown on the standard

media produced luxuriant growth. White tufts appeared on corn meal agar, but vagrant threads of these on being transferred to synthetic medium No. 2 gave rise to dark gray growth with several black pycnidia. No further work was done with this organism.

*Colletotrichum lindemuthianum*, Strain I

Two single-spore isolations were made. These were grown on the standard media. White tufts appeared on the corn meal and oat meal agar cultures, but transfers of these to corn meal flasks and oat meal agar slants gave black, apparently normal, cultures. Other attempts described later failed to establish a white strain.

*Colletotrichum lindemuthianum*, Strain II

This fungus was known to be more variable than the preceding one. Five single-spore isolations were made and the

FIG. 2. Cultures of white form of *Colletotrichum lindemuthianum* (*a*), the parent form of *Cladosporium fulvum* (*b*), and the variant form of *C. fulvum* (*c*)

organism was grown on standard media. Many white islands appeared, especially on corn meal and on oat meal agar, and these variations proved to be remarkably constant. Isolation

5 on corn meal produced white tufts of mycelium twenty days after inoculation. Bits of the white mycelium were transferred to oat meal agar, synthetic agar No. 2, prune juice agar, corn meal agar, corn meal; and from these, fifteen subsequent transfers were made throughout the summer on a variety of media. The fungus produced only a white compact mat with very little aërial mycelium. This variant was used in our later studies (see Fig. 2).

*Cladosporium fulvum*

Four single spore isolations were secured as described. When grown for twenty days in corn meal, Isolation 4 showed a small white island arising from the center of a thick mass of small, normal, olive-green clumps (Plate VIII, Fig. 1). An attempt to pick off the colorless hyphae and grow them on corn meal and oat meal agar failed, presumably because spores were taken along with the white mycelium. On a second attempt the white hyphae were successfully transferred from a culture of the parent strain to prune juice agar, synthetic medium No. 2, corn meal agar and oat meal agar. The laboratory media used, besides those to be discussed later, were Coons' synthetic agar, corn meal, steamed rice, raspberry leaf agar, standard nutrient agar, Czapek synthetic agar and lima bean infusion agar.

Besides Isolation 4, the other single-spore isolation cultures developed white patches at different times and in many cases isolations were secured. Table I presents an account of the appearance of these variations in the different strains and on the different media used. It is evident that the forms occur repeatedly and upon widely varying nutrient media. The different white forms from the various single-spore cultures appeared identical.

It should be noticed that these so-called white forms are not perfectly white, but have a pink or lilaceous tinge in the hyphae. Makemson (20) and Spangler (28) have described the growth of *Cladosporium fulvum* on the host and on the different culture media, giving measurements and drawings of the mycelium, conidiophores and conidia. The parent strain used in these experiments is from the original isolation made by Makemson.

Camera lucida drawings of the material from the parent and an aberrant culture were made (Plate IX). No material differences were found between the young growing mycelium of the parent and variant. The mycelium of the parent strain is about 2 $\mu$ wide, hyaline, quite delicate and of irregular septation, branching at a right angle or at an angle of 45 degrees. The cell contents are rather granular. The aërial mycelium of the variant is much wider (up to 4 $\mu$ in width), is very granular, and shows occasionally irregular inflations resembling chlamydospores. The mycelium, except for the uneven septation, resembles the conidiophores of the parent, but no conidia were ever seen on the variant form. The inflations mentioned have been described by Makemson (20) in normal cultures on corn meal agar. The parent form produced an abundance of conidia.

The striking difference between the variant and the parents, therefore, seems to be the lack of conidium production in the variant. The mycelium of the parent form is hyaline and the olive-brown appearance of the culture seems to be due to the conidia and the conidiophores. The variant form lacking these structures appears white or paler than the parent (Fig. 2 *c*). Light purple or pink color develops in the variant when grown on certain media (corn meal agar, prune juice agar, Czapek dextrose agar). The pink color appears most readily on alkaline media and with media rich in sugar. Table II give a comparison of the parent and variant forms on various media.

A study of the table reveals that both parent and variant showed different colors on the different media, but the variations were along parallel lines. The parent form varied along the olive-tawny shades, while the variant in the white-pink-lilac shades. The variant showed no tendency to develop patches distinct from the rest of the growth, while the parent form in various media continued to produce the "white islands." No spores were produced by the variant at any time on any medium.

### EXPERIMENTS WITH SYNTHETIC MEDIA

In order to determine something of the influence of the nutrient salts and sugar on the color production, fruiting and

production of variants by the fungi under investigation, the following experiments were conducted.

Coons' synthetic solution (8) was devised with the aim of inducing sporulation. By increasing or decreasing the proportions of the salts above and below the optimum concentrations for this medium, a range of conditions was obtained. It was hoped that these experiments might further show whether it was the excess or lack of particular food material that induced the variations.

Coons' solution [1] is made of the following ingredients:

| | |
|---|---|
| M/5 Maltose | 5 cc. |
| M/5 Asparagin | 1 cc. |
| M/5 Potassium acid phosphate | 5 cc. |
| M/5 Magnesium sulphate (crystal) | 1 cc. |
| Distilled water | 88 cc. |

By arranging the numbers of cubic centimeters of these nutrients (M/5) in a series according to the triangle system (25) and adding 2 per cent agar and enough water to make up 100 cc. of solution, fifteen solutions of varying proportions were obtained (Table III). The amount of magnesium sulphate was held constant in all the cultures. Maltose and potassium acid phosphate were used in greater and lesser amounts than the amount given in the regular formula. Asparagin was used in an increasing series. The solutions were designated by four-figure numbers in which the first digit stands for the number of cubic centimeters of M/5 maltose in 100 cc. of medium, the second for the number of cubic centimeters of M/5 potassium acid phosphate,

[1] This synthetic solution is made for laboratory use as follows:

| | |
|---|---|
| Maltose | 3.6 gms. |
| Asparagin | 0.26 gms. |
| Potassium acid phosphate | 1.36 gms. |
| Magnesium sulphate (crystal, $7H_2O$) | 0.49 gms. |
| Distilled water to | 1000 cc. |

Steam on three successive days. *Do not autoclave.* The slight opalescence which develops when the solution is first made disappears rapidly. The pH of the solution is approximately 5.2.

Synthetic solution No. 2 has the same ingredients as the medium described above, but has five times as much asparagin.

the third for the number of cubic centimeters of M/5 asparagin and the fourth for the number of cubic centimeters of M/5 magnesium sulphate. For example, the number for the regular formula of Coons' medium is 5511, meaning 5 cc. M/5 maltose, 5 cc. M/5 potassium acid phosphate, 1 cc. M/5 asparagin and 1 cc. M/5 magnesium sulphate per 100 cc. of medium.

The ingredients were mixed in the correct proportions and the necessary amount of water containing melted agar was added to make 100 centimeters of medium. The amount of agar added in each case was sufficient to give a 2 per cent solution. The medium was tubed, steam-sterilized on three successive days and then slanted. It should be noted that in these experiments the reactions of the various combinations differed as did also the osmotic pressures. These experiments merely present a wide range of nutritional combinations.

Since in this experiment variations in color as affected by food supply were to be observed, as well as the behavior of the variant forms under different nutritional conditions, it was thought best to use solid media where the color could be better observed and compared. It was, therefore, impossible to determine the exact weight of mycelium produced. However, a similar series, but without agar, was prepared in 60 cubic centimeter Erlenmeyer flasks, each containing 20 cubic centimeters of the liquid media and *Colletotrichum lindemuthianum*, Exp. Sta. Strain II grown. This experiment will be described in detail further on.

*Septoria apii*, *Colletotrichum lindemuthianum*, Exp. Sta. Str. I and II, and *Cladosporium fulvum*, both parent and variant, were grown in duplicate on the triangle series of solid media as described above. The following is an account of the behavior of each fungus on these varying combinations of nutrients.

*Septoria apii*

There was no noticeable variation in color of this fungus grown on a set of media as described above. The fungus in all combinations of nutrients produced black mycelium with an abundance of pycnidia. There were differences in the amount of growth in the various media, as may be observed in the picture

of the set taken seventy days after inoculation (Plate X). The darkest color and heaviest mat developed in the cultures at the top of the triangle where sugar was present in the greatest proportion, 5421 and 6411 being the cultures making the best growth. It may also be seen that a small white tuft appeared on 3531 and 3621 of the base line of cultures. The decrease in the proportion of phosphorus seems to have influenced growth much more effectively than the decrease in the proportion of nitrogen in the form of asparagin, sugar and magnesium being constant. It should be noted that the potassium content varied also in these cultures, since potassium acid phosphate was the salt used.

*Colletotrichum lindemuthianum*, Exp. Sta. Strains I and II

Each strain was grown on a set of media as described above. The behavior of the two strains was similar. The tubes were inoculated with spores and the cultures were allowed to grow under natural conditions, side by side in the laboratory. The photographs (Pls. XI and XII) were taken seventy-five days after inoculation and give a good idea of the appearance. Acervuli with the characteristic salmon-pink spore exudate developed normally on all of them, independently of the black color, as, for example, in cultures with an excess of nitrogen, the black color developed very much later than the acervuli. The same thing had been noted previously with the synthetic medium No. 2. The greatest growth occurred in the cultures having the most sugar and potassium acid phosphate and there was a decrease in intensity of color as the amount of sugar decreased and phosphorus increased. Not a great number of white tufts developed. Several white patches were observed in culture 5511 (normal Coons' medium) of Strain I, but on being transferred to oat meal agar, corn meal agar and corn meal (flasks), they invariably became black.

The variations in the amount of growth may be better considered from the data of the liquid culture experiment. Twenty cubic centimeters of each medium in the set was placed in a sixty-centimeter Erlenmeyer flask and inoculated with 0.1

centimeter of a spore suspension of the fungus. The cultures in duplicate were grown at room temperature on clinostat for seventy-six days. At the end of this period careful notes were taken, the flasks were photographed (Pl. XIII), and their contents filtered on weighed filter paper. The mycelial mat and the filter paper were dried to a constant temperature and reweighed. Table IV records the weights of the duplicates in each medium, their average and descriptions of their growth and color.

The mycelium from the different flasks was examined microscopically. The black or brown pigment was found in the mycelium. The bodies referred to in the table above as black sclerotia were tiny tangles of mycelium. Sporulation was found correlated with the color. Brown or white mycelium showed no spores. Transfers from several flasks showing white mycelium to oat meal agar invariably became black. This seems to indicate that the variations in color were not fixed, but were due to nutritional factors which prohibited the formation of spores, especially towards the potassium-phosphorus side of the triangle.

*Cladosporium fulvum*

This organism was more responsive to the various nutrient combinations than any of the fungi under study. Both the brown and the white forms were grown on a set of media as described above and the results were very interesting, especially the variations in color. This fungus makes a slow and moderately abundant growth and it seems that there was enough food for its development in all the cultures, since there was very little variation in the amount of growth. The variations noted were (1) the color of the aërial part of the colony, (2) the substratum color and (3) the color of the submerged growth. The growth on media 5421 and 3441 seemed to be a little more abundant than on the others.

As regards the color diffusing through certain media, it had been noticed that the color on oat meal agar and corn meal agar was maroon and a similar pigment appeared on Media 4341 (Van Dyke red) and 3441 (faint Van Dyke red). These combinations are at the nitrogen corner of the triangle. In the rest

of the media the submerged growth was of a brownish-olive color tinged more or less with ochraceous-tawny especially towards the sugar side.

The color of the aërial part of the colony varied considerably according to the composition of the medium. In general it was brownish towards the sugar column, pinkish towards the nitrogen side and olive towards the potassium-phosphorus side. The intermediate cultures merged one into the other. White mycelium appeared in Media 5331, 5421, 4431, on the sugar-nitrogen side of the triangle. Table V gives the colors observed on the different media. The first line in each case is the surface color, the second the color of the submerged growth, the third the color variations in surface, the fourth the color diffused through the medium. The number after each color refers to the plate in Ridgway's *Color Standards*.

*Cladosporium fulvum*, variant form

The white strain of *Cladosporium fulvum* was also grown on a similar series of media. Table VI gives the colors observed on the different media. The growth was uniform in size of colony, 0.5 to 1 cm. in diameter, except on 3351 where the colonies were from 1 to 3 mm. in diameter. The white character of the variation was preserved throughout unchanged, except that a yellowish tinge developed towards the sugar side, purplish towards the nitrogen side and yellow-pink towards the potassium-phosphorus side. On account of the purple tinge the white was more striking upon the nitrogen side.

These tests with various combinations of nutrients threw very little light upon the problem under consideration. No particular combination seemed to influence the production of "white islands," although in several cultures with the various fungi the aberrant forms appeared. There was no regularity in their production. With *Cladosporium fulvum* a few "white islands" appeared in the cultures of the parent form, but in general these cultures showed the color typical of the growth on ordinary media — brown olive. The variant remained sharply differentiated in color production from the parent form.

### EFFECT OF LIGHT ON VARIABILITY AND COLOR OF *CLADOSPORIUM FULVUM*

Microörganisms in general are negatively phototropic under strong light. Direct sunlight is detrimental to most bacteria although some fungi are resistant to it. Fungi grow well and fruit regularly in diffused daylight, which in many instances seems to be an essential factor for reproduction. Coons (8) found that with *Plenodomus fuscomaculans* light is a factor directly concerned with pycnidium production, the fungus refusing to fruit when kept in the dark, irrespective of nutrition, aëration, substratum or strain. Makemson (20) found that light had a retarding effect upon the growing germ tubes of *Cladosporium fulvum*, but that the ultimate length was the same. Vegetative growth and sporulation were also more profuse when the fungus was grown in the dark. Stevens (29), working with *Helminthosporium spp.* grown on Petri dishes, observed slightly less zonation and less aërial mycelium in the dark than in the light. Smith and Swingle (27) report that diffused daylight affected considerably the color of Fusaria, and Sherbakoff (20) found that diffused daylight intensifies the color of Fusaria, while intense light dulls it. They did not find light influencing other characters in Fusaria. Older literature reviewed by Coons (8) is just as contradictory. It seems that the different fungi vary in their responses to light of different intensities, some vegetating best in darkness and requiring the light stimulus to induce fruiting, others growing and fruiting best in diffused daylight or in darkness.

In order to determine whether light had any effect on color changes and variations of the fungi under study, four sets of media, as described in the preceding section, were inoculated with the white and brown strains of *Cladosporium fulvum*. A set of each strain was grown under a bell-jar completely darkened to exclude light. A second set of test tubes arranged and fastened on the walls of a battery jar, covered by a bell-jar, was exposed to strong diffused light and slowly rotated to overcome differences in intensity. Air was circulated through both bell-jars.

The jars were not disturbed until the end of the experiment, when the colors of the cultures in both sets on each medium were studied and pictures taken. A detailed description and comparison of the cultures on each medium in light and dark are not given, since the slight variations in color between the light and dark series did not seem consistent nor in any definite direction (see Pls. XIV-XVII).

In general light did not seem to affect markedly the color, growth of the colony or the number of "white islands," and it would seem that *Cladosporium fulvum*, both parent form and variant form, is indifferent to the light stimulus, and furthermore, light does not play any rôle in calling forth the formation of "white islands."

### EFFECT OF REACTION ON VARIABILITY AND COLOR

The reaction of the substratum has recently been recognized as one of the most important environmental factors influencing the physiology of plants. It had formerly been thought that adjusting the reactions of the medium used, by some sort of titration, to a point above or below the turning point of an indicator, usually phenolphthalein, was a satisfactory method of securing an optimum reaction for microörganisms. However, with the discovery and perfection of methods for measuring the active acidity in media, investigations have shown that the hydrogen ion concentration should be classed with temperature, light and moisture as an important environmental factor. It was also found that, besides influencing growth in general, the reaction has an effect on color production, fruiting, zonation, and the like.

Sherbakoff (24) in 1915 found that acidity induces the production of red color in those Fusaria which make a grey-white growth on neutral media. Acidity also lowers the rate of growth and makes zonation prominent. Fungi are able to withstand a comparatively wide range of pH variation. Meacham (21) in 1918 found that *Lenzites sepiaria*, *Fomes roseus*, *Merulius lachrymans* and *Coniophora cerebella* would grow from pH 5-1.7 on the acid range. Webb (30) in 1919, studying the germination of spores of different fungi at different pH, found that the range of

spore germination with respect to the reaction of the medium is between pH 2–10 with maxima at pH 3–4 and 7. Johnson (16) in 1923 found that the reaction best suited for the growth of molds lies towards the acid range of the neutral point. Goss (14) in 1924 found that *Fusarium eumartii* is capable of growing under a wide variation in the hydrogen ion concentration on 2 per cent dextrose potato agar. At optimum temperature no appreciable difference was seen in the growth on media varying in pH from 4.5 to 8.5. Hopkins (15) in 1922 found that by adding 3 drops of 50 per cent lactic acid to 20 cc. agar, a strain to *Colletotrichum lindemuthianum* which produced few spores in neutral potato agar sporulated freely.

In order to determine the effect of reaction of medium upon the fungi under investigation, the following experiments were undertaken. Since the variations, "white islands," observed were characterized by a lack or modification of pigment and the suppression of sporulation, it was thought best to use two kinds of media; one favoring fruiting and the other favoring vegetative growth. Coons' medium was found by its originator actually to favor fruiting and the behavior of *Sphaeropsis malorum* in the present investigation also indicated the tendency of this medium to induce spore formation. Richards' medium E (23) has been frequently used by many investigators as a general synthetic medium with good results. The modification by Karrer and Webb (19) was used in order to avoid the precipitation of the phosphate in the alkaline members of the series. Liquid media were used in this experiment and the filter paper cone preparation dish method was adopted (8). This method consists in growing the fungus on a filter paper cone placed in a small preparation dish with 10 cc. of medium. Schleicher and Schull No. 595 (7 cm. in diameter) paper was used. The preparation dishes about 5 cm. in diameter and 3 cm. deep, were protected against contamination by placing them in large moist chambers or under bell-jars. Under such conditions the fungus grew on a solid substratum of pure cellulose kept at constant saturation. Both the white and the parent strains of *Cladosporium fulvum* and *Colletotrichum lindemuthianum*, Exp. Sta. Str.

II, were grown in duplicate series of ten different hydrogen ion concentrations varying from pH 2 to 8.4. Besides the paper cone cultures, the fungi were grown in an exactly similar series of media in test tubes with the proper indicator added to the medium. The purpose of this experiment was to determine as nearly as possible the shifting of the pH by the growth of the fungus.

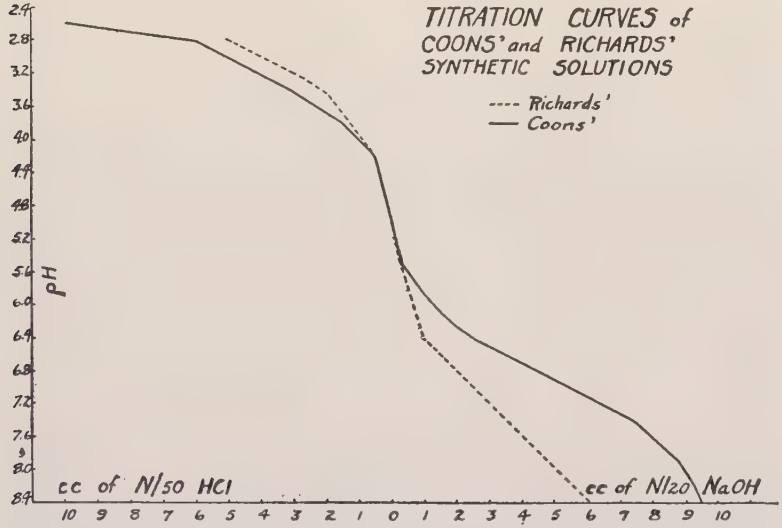
TITRATION CURVES of
COONS' and RICHARDS'
SYNTHETIC SOLUTIONS
---- Richards'
— Coons'
pH
cc of N/50 HCl
cc of N/20 NaOH
10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10

FIG. 3. Titration curves of Coons' and Richards' synthetic solutions

Previous to starting the experiment the titration curves of both media to be used were determined. Karrer and Webb (19) report a titration curve for Richards' medium E modified, but we were unable to duplicate their findings. The pH of Richards' solution is given by them as 4.6, but with the particular chemicals, apparatus, etc., with which the writers worked, it was found to be 5.0. This finding necessitated the retitration of the medium. Table VII gives the number of centimeters, the normality of acid and alkali, and the number of centimeters of water to be added to 25 cc. of double strength medium to make 50 cc. of medium of a desired pH and of the proper concentration in nutrients. It was found that by using weaker solutions of acid

and alkali than those recommended by Karrer and Webb (19), a smoother curve could be obtained. Figure 3 gives the titration curves. Table VIII shows the change in uninoculated media after one and a half months. In general the Coons' medium held constant, while the Richards' medium in the alkaline range became weakly acid.

The preparation dishes with the filter paper cones in place were sterilized in the dry air sterilizer while the medium, the water and the acid or alkali, were autoclaved separately. The proper amounts were mixed and pipetted into the tubes and the preparation dishes by means of sterile pipettes. A suspension of spores was used as inoculum in the case of the parent strains of *Colletotrichum lindemuthianum* and *Cladosporium fulvum*, but in the case of the variants of both fungi a bit of mycelium was used.

*Cladosporium fulvum*

The cultures were grown in the dark. Twelve days and again in one and a half months after inoculation, the color, the relative amounts of growth and in the case of the test tube cultures, the pH, were noted. Tables IX and X summarize these observations for test tube cultures, and Table XI summarizes the results obtained with filter paper cones.

With the Coons' medium the parent form grew well on a range of pH 2.8 to pH 7.6, producing in the submerged portions the dark olive-green color typical of the submerged growth of this organism on ordinary media. The aërial growth of this was of a light yellow-olive color. A purplish color (vinaceous-lilac, daphne-red) was produced towards the alkaline side of the series and this color is characteristically produced in old cultures on oat, corn meal and prune juice agar. The same purplish color was observed in the variant strain also in the alkaline cultures. "White islands" appeared in both acid and alkaline cultures with Coons' medium.

There was a greater variation in the color of the aërial growth on the Richards' series, but there was no characteristic distribution, the same color being found on both the acid and the alkaline side. No purple tints were found on either the parent or the

variant with this medium. On the contrary the buff color characteristic of the variant when grown in acid media was found throughout the series on this medium. It is not sure that the alkaline tubes of Richards' medium remained in this condition under the action of the air, since the solution is poorly buffered. In general, as has been observed by many investigators, fungi given abundant carbohydrate tend to shift the reaction of an alkaline substratum towards the acid side and this was the case in the experiments just described. After one and a half months final notes were taken. It will be seen that in the case of both forms the tolerance of acid and alkaline conditions is practically the same; the effects of the parent and variant strain upon the medium, taking into account the relative growth, are alike. The distinctions in color are maintained; and what is perhaps the most significant, in spite of the great variety of growth conditions presented, there is a complete absence of sporulation in the variant as contrasted with heavy spore production in the parent forms in some cultures. The differences of the two forms manifested in the previous work seemed to be largely maintained.

*Colletotrichum lindemuthianum*

Similar observations were made on the parent strain and the variant of *Colletotrichum lindemuthianum*. These results are tabulated in Tables XII and XIII, for the Coons' and the Richards' media respectively. It will be noted that the parent form produced spores throughout the range in which it grew, whereas the variant form produced no spores at all. The growth range was approximately the same, with slight variations in amounts of growth produced. On filter paper cones saturated with Coons' medium the fungus seemed to revert to the parent form, so far as vigor of growth and color of mycelium are concerned (Table XIV). No spores were found, however. These results seem rather significant in view of the uniform white growth in other tests of the fungus on various media and under other conditions, and seem attributable to the more favorable conditions for growth afforded by the use of the filter paper cones

which doubtless favor aëration, removal of toxic byproducts and other growth-controlling factors.

## EFFECT OF TEMPERATURE AND REACTION ON COLOR AND GROWTH

### *Cladosporium fulvum*

In connection with another experiment, carried on in Berkeley, California, both parent and variant strains of *Cladosporium fulvum* were grown on plated Shive's best dextrose agar [2] (26) varying in pH from 4 to 8 and kept at 30–32° C., 20° C. and 10° C. The medium was prepared in lots of one liter, brought to the desired hydrogen ion concentration by the addition of acid or alkali at rates determined by Sideris (26), tubed at the rate of exactly 10 cc. per tube and steamed for one hour on three consecutive days. Duplicate plates were poured, allowed to cool and inoculated in the center. They were wrapped in paper and kept at a constant temperature, as mentioned above. At intervals the plates were examined for color and rate of growth.

Table XV gives the growth of the fungus (diameter of colonies in millimeters) and color of the aërial and submerged part, three, eight and fifty-four days after inoculation at the three temperatures used.

Makemson (20) found that the temperature limits for best growth of this fungus were rather narrow, being between 20° and 25° C. In this experiment no growth occurred at 10° C. and only slight growth was noticeable after fifty-four days. Temperature, therefore, did not enter as a factor in this experiment. The variant was found to be a more active grower than the parent strain, as indicated by the colony measurements, and both parent and variant seemed to grow rather uniformly within the hydrogen ion concentration limits of the experiments.

[2] The composition of this medium is as follows:

| | |
|---|---|
| $MgSO_4$ | 2.12 gms. |
| $Ca(NO_3)$ 2 per cent | .71 gms. |
| $KH_2PO_4$ | 1.36 gms. |
| $FeNO_3$ 5 per cent | 1 drop |
| Dextrose | 20 gms. |
| Water | 1000 cc. |

As regards the color, this experiment confirms the results of the previous experiments on the effect of the reaction on the medium. No striking variations were seen even between the extreme ends of the series, in either the variant or the parent, except perhaps the development of the purple color in the variant towards the alkaline end, as had also been observed in previous experiments. A repetition of this experiment gave similar results.

### PATHOGENICITY

The majority of the variations induced through unfavorable environmental conditions have been among the saprophytic fungi and bacteria. Of the spontaneous variations or mutations reported in pathogenic fungi a few do not show reduced pathogenic action, though in others the reverse is true and in still others data are lacking.

Edgerton (13) found that the Glomerella mutant reported by him grew very slowly on apple. The Brachysporium mutant reported by Bonar (3) was not pathogenic on white clover and came from a parent of reduced virulence due to artificial cultivation for many generations. Bennett, who, according to Coons (1), investigated white forms developed from a culture of *Phoma apiicola*, found that they are also attenuated forms. On the other hand Crabill's Coniothyrium variant (10) was pathogenic, as also was the Glomerella variant reported by Dastur (11) and the Botrytis reported by Brierley (4). Definite information is lacking in the cases reported by Burger (6) and Stevens (29).

*Cladosporium fulvum*

Four potted plants of the Stone variety of tomato were used in these experiments. Two of them were inoculated with the parent strain, and the other two with the variant strain of *Cladosporium fulvum*, the inoculations being made in separate rooms of the laboratory under the usual aseptic conditions. A drop of sterile water placed on the lower or upper surface of a leaflet, was inoculated with a little mycelium from a young vigorous culture and covered with a fleck of sterile cotton.

Many leaflets were inoculated in this manner. Each plant was then put under a large glass bell-jar for five days and kept exposed to light near a north window of the laboratory at 20–25° C. After this period the plants were brought into the greenhouse. The experiment was repeated with four potted plants of the Beauty tomato variety.

The results of the inoculations were as follows: Both the parent and the variant produced spots at every point of inoculation, more than thirty spots being counted in each case. No spots were seen at other than the inoculation points and although these plants, together with many control plants, were kept in the same greenhouse there was no natural infection. The spots produced by the parent strain were all characteristic of the disease as described by Makemson (20). There was an olivaceous growth on the under side of the leaf with an abundance of spores characteristic of the fungus. The upper surface of the leaf in the infected area turned yellow and became dry. The spot spread irregularly from the point of inoculation.

The spots produced by the variant strain were elliptical and well defined, rather dry with yellowish flakes on the surface. There was no mycelial growth on the under side of the leaf. Free-hand sections through the infected portion of the leaf showed the presence of mycelium throughout the leaf tissue. Five plates were poured from leaves infected by the variant and Czapek dextrose agar was used for a medium. In every case the white form of Cladosporium grew on these plates. Similarly infected leaves were placed in moist chambers. The white variant grew from the margin of every spot. Plates from tissue infected by the parent strain showed an abundance of growth of the typical *Cladosporium fulvum*.

Plate XVIII shows leaflets of tomato artificially infected with both forms of Cladosporium. Isolations were made from the part of the leaf infected both by the parent and the variant strains and reinoculations were made on potted Beauty tomato plants in bloom. The methods used were those described above, except that inoculations were made on both the upper and lower sides of the leaflet. No spots were produced from upper-surface

inoculations. Typical spots similar to those described above developed on all (fifteen) of the lower surface inoculations. Inoculations on the calyx and the stem of flowers produced characteristic spots. Small tufts of white mycelium were found at the margin of the spots produced by the variant. Such tufts were examined under the microscope for spores. There were no typical spores except a few spore-like bodies believed to be chlamydospores. The mycelium was thin, densely branched, and purple.

The parent form of *Cladosporium fulvum*, although it had been under artificial conditions for over four years, produced the typical leaf mold disease.

Dastur (11) found that passing the variant form of Glomerella through its host restored its lost spore-producing power, but this was not evidently the case with *Cladosporium fulvum*, since it did not produce spores even after passing through its host a second time. From the experiments described above, it becomes evident that both the parent and variant are parasitic on the tomato plant, but passage through the host does not immediately restore the color or fruiting capacity of the variant.

*Colletotrichum lindemuthianum*

Golden Wax bean plants were inoculated with the parent and variant form of *Colletotrichum lindemuthianum*, Exp. Sta. Strain II; spores or bits of mycelium were used in the same manner as in the tomato plant inoculations. Inoculations were made on both the upper and the lower surface of the leaves. No spots were formed on any of the upper-surface inoculations or on the control leaves. The results were not as definite as in the case of Cladosporium. The leaflets inoculated with the white form of Colletotrichum turned yellow, but no definite spots developed except in one case where typical anthracnose spots were observed. No spores were found. The leaflets inoculated on the under surface with the black form of Colletotrichum showed typical spots of anthracnose with an abundance of spores.

SUBSEQUENT HISTORY OF THE CULTURES

In August, 1923, culture work with these forms was discontinued at the laboratory and the cultures were carried along by frequent transfers as stock cultures. The results of these transfers are as follows:

Examinations made in 1924 and early in 1925 showed that the marked difference between the parent strain and the variant had largely disappeared. The variant had practically the color of the parent form and on some media produced more nearly the typical color of normal *Cladosporium fulvum* than the parent form. The parent form had ceased to sporulate in our cultures and no spores have been found in cultures of the variant strain. An interesting development was the production of "white islands" in the cultures of the variant form. On subsequent transfers the variant form continued to develop the color normal for *Cladosporium fulvum*.

*It is our opinion that these forms are not as distinctly different as when the first isolations were made.*

It would seem that these forms, though markedly different when isolated, if supplied with proper conditions, return to the parent form, or at least to what approaches it fairly closely.

It will be noted from the experiments that *Septoria apii*, *Sphaeropsis malorum*, *Colletotrichum lindemuthianum* and finally *Cladosporium fulvum* have all given off sterile mycelia which have been of different color from the parent strain. All these have eventually reverted to the normal or nearly the normal form. The case is not completely clear since sporulation has not been obtained with the several variants, but we would question strongly any "specific" difference between the variant and parent forms under observation.

DISCUSSION

From the experiments here outlined the following statements can be made:

1. In single-spore cultures of a number of fungi, variants occurred repeatedly. Those with which we have been concerned

have been the white forms — the sterile patches cropping up here and there in cultures. The sterile patches we have called "white islands."

2. Various modifications of the environmental factors have been tried and these have exercised profound effects on the colors and fruiting habits of the various fungi, especially *Cladosporium fulvum*. These modifications have not, however, been found to be the essential factors inducing the type of variation under consideration. The white forms, on the contrary, have come at unprognosticated and irregular intervals in the various strains under observation.

3. When once isolated, some of these variants have been strikingly constant in spite of culture under a wide range of conditions, such as variations in type of substratum, variation in percentage composition of medium and even life on the host as an active parasite.

4. On the other hand some isolated variants apparently revert at once to the normal form. Others, as in the case of *Colletotrichum lindemuthianum*, Strain II, after long sojourn in culture suddenly revert to the parent or at least to the color of the parent form. The most constant of the forms under investigation, the atypical form of *Cladosporium fulvum*, remained for two years entirely distinct from the parent. The striking thing was its change back to normal color by subsequent culture on a different medium (potato dextrose agar) from the ones tried in the experiments. As yet sporulation has not occurred. The parent culture in the meantime has ceased to sporulate. An interesting development is the production anew of "white islands" in the reverted form.

The nature of variation in plants and animals is a subject which in the last hundred years has received great attention and today is occupying by far the greatest share of attention at the hands of biologists. That mutations do occur in apparently pure line cultures of plants and animals is attested in a great variety of contributions covering the whole range of plant and animal life.

The significance to be attached to the various contributions depends in large measure upon the definition of the problem

and upon the criteria of purity established in the cultures. De Vries in his monumental work on *The Mutation Theory* does not make any discrimination between the terms 'saltation,' 'mutation' or 'sport' and he uses them more or less interchangeably. The Darwinian term 'single variation' is used to designate the same thing. The essential element in the De Vriesian concept was the suddenness of the change, its constancy, and its difference from the ordinary fluctuating variation brought about by environmental influence.

But the work of De Vries preceded the vast amount of cytological and genetic work and the modern concept of mutation has been of necessity molded in its interpretation by the later contributions. Today by common agreement, mutation is taken to mean a change in the *genetic constitution*, or, as Brierley (5) describes it, "a genotypic change in a pure line." In his thoughtful essay, *Some Concepts in Mycology*, Brierley has established the following criteria of a true mutation:

> There are certain evident minimal requirements for any studies to this end which may perhaps be expressed as follows:
>
> 1. In order to ensure specific purity the organism must be a single individual of a tested pedigree pure line.
> 2. The whole life-history of the organism, together with the range of its plasticity both morphological and physiological, must be accurately known in the minutest detail.
> 3. No organism in which sexuality exists, or it is conceivable that it may exist, must be used unless its gametic constitution and genetic behavior under all conditions of the experiment be known.
> 4. Possible contamination by filterable gonidia must be eliminated.
> 5. Adequate control experiments must be maintained (a little matter but one absolutely vital, which has escaped the attention of many students of the lower organisms).
>
> Unless these five conditions are rigidly maintained in the focus of one's attention, and exactly complied with, the results obtained in experimental studies on the educability of microorganisms can have but little value.

The variations of fungi and bacteria when grown in apparently pure line cultures recorded in the literature are numerous. These variations range from those quickly reverting forms to apparently stable forms which various authors have denoted as mutants. Other names have been employed — saltations, sports, and variants being used by various authors and

with varying connotations. The literature of variation in fungi has been carefully summarized by Brierley (4) and Stevens (29) and the extensive bacteriological contributions have been exhaustively summarized by Dobell (12), Jordan (17) and Jollos (18). This mass of literature needs no extensive review. The various authors have attempted to fit the terminology and criteria employed to those in vogue with higher plants. It is a common property of much of this work that several assumptions have been made, namely, that the cultures used have been pure lines representing homozygous entities and that with the bacteria, at least, the material dealt with has concerned itself with organisms in which sexuality and cell fusions need not be considered.

It is to be noted that Brierley (4) in his work with Botrytis has in a remarkable manner departed from those fixed assumptions and, in the absence of cytological evidence, he declines to consider as a true mutant the white sclerotial form developed in his culture of Botrytis, but rather explains the development of the aberrant form as resulting from contamination from some preceding anastamozing or fusion of cells. Similarly, Stevens (29) employs the term saltation to cover variations in an organism where cytological conditions and sexuality are unknown.

Variations in fungi have been induced through exposure of cultures to unfavorable environmental conditions, such as high temperature, toxic substances, unbalanced nutrients and the like, but few if any of these contributions meet the standards erected by Brierley. In part the earlier work has dealt with selections of those individuals in the culture which were resistant to extremes and, in the absence of exact knowledge of the nature of the parent culture, may be regarded as the separation of the culture with its pure lines.

New developments in science bring about modifications of old notions. Brierley (5) has insisted that possible contamination by "filterable gonidia" must be eliminated. The recent work on the "bacteriophage," or transmissible lytic principle, makes very clear the importance of close scrutiny of the bacteriological material in order to be sure that "pure" cultures are ultra-pure. No intimation exists in the literature that we are to suspect

fungous cultures of being similarly contaminated, but such a possibility must not be overlooked.

One can but agree with De Vries that nothing is more variable than the meaning of the word variability and perhaps the word 'mutation' may be substituted for 'variability.'

The confusion of ideas surrounding the term has lead several writers to avoid it altogether. Morishima (22), in 1921 reporting several cases of adaptive changes in bacteria, *B. typhosus* in particular, thinks that the term mutation should be used only with higher plants and should not be introduced into bacteriology "for the bacteriologist, who studies his species not only from the morphological point of view, but also with regard to biochemical and immunological reactions, and who observes not a few generations only, but hundreds and thousands of generations, would almost surely have to modify the conception of the term in such a manner as to cause confusion to the botanist. It, therefore, seems advisable to leave the term mutation to the botanist and, for the present at least, to speak of atypical varieties of bacteria or simply variants."

Stevens (29) uses the term saltation with a new meaning to cover variations in non-sexual generations of fungi. Chaudhuri (7) follows his example for the same reason.

By nearly all the criteria ordinarily employed in judging "mutants," it might seem that in this work we are dealing with definite mutant forms. Had the work stopped after a few transfers, such a status might have been claimed. Nothing striking in the way of a new species had been produced, the condition inducing the production was unknown, but, nevertheless, the forms were atypical, were easily recognizable from the parent form, and were constant enough in culture to satisfy ordinary standards. In addition marked differences in pathogenicity to the host were obtained.

But the reversion of these fungi to the parent form or what closely resembles it, is in our opinion the striking thing in the behavior of these strains. Some reverted at once to the normal, others after many transfers, and *Cladosporium fulvum* after years of cultures on media.

It is the opinion of the writers that the variants dealt with in this paper represent rather semi-permanent variations which are different from the parent form somatically rather than genetically. These are the "dauer-modifikations" of Jollos (18), which perhaps by drying of the mycelium and lack of nutritional connection with the substratum, have become changed from the normal. With respect to certain attributes they may be looked upon as attenuated forms. Instead of being new species they are rather to be looked upon as cultures lacking certain physiological powers. They resemble in some respects the *Abkulturs* of Fusaria and the so-called attenuated cultures of bacteria and fungi. They may have arisen from cells whose protoplasm has been poisoned, or perhaps affected by some unknown biological factor, and which are tardy in recuperation until supplied with the necessary conditions. This study illustrates that the criteria established for proof of the educability of fungi are necessary and that what may seem plausible evidence of the establishment of new forms in pure cultures needs careful and protracted investigation.

SUMMARY

White variants were isolated from known single-spore cultures of *Septoria apii*, *Sphaeropsis malorum*, *Colletotrichum lindemuthianum* and *Cladosporium fulvum*. The variants of *Septoria apii* and *Sphaeropsis malorum* reverted at once to the parent form. From the other two fungi strains were obtained which remained constant on laboratory media for over two years. These forms were lacking in the color characteristic of the parent forms and did not sporulate.

Nutrients, light and dark, reaction of substratum were not found to be the controlling factors leading to production of the variants.

The variant forms remained fixed under a wide range of environmental conditions.

The variant forms were pathogenic to their respective hosts, but the disease produced by the *Cladosporium fulvum* variant was not like the typical disease produced by *Cladosporium fulvum*.

All the forms eventually have regained the color of the parent form, but not the capacity for spore production.

These variants are looked upon as modified forms whose behavior is analogous to that of *Abkulturs* of Fusarium and the so-called attenuated cultures of fungi and bacteria.

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## TABLE I

THE APPEARANCE OF ACHROMATIC VARIATIONS IN FOUR SINGLE-SPORE STRAINS OF *Cladosporium fulvum* Cke., OTHERWISE IDENTICAL, ON A SERIES OF STANDARD MEDIA

Positive cases marked: ++ ; negative: −− .

| MEDIA | Strain I | Strain II | Strain III | Strain IV |
|---|---|---|---|---|
| Corn meal agar | | | | ++ |
| Corn meal flask | −− | −− | ++ | ++ |
| Rice flask | −− | −− | −− | −− |
| Prune juice agar | −− | −− | −− | −− |
| Oat meal agar | ++ | ++ | ++ | −− |
| Synthetic agar No. 2 | ++ | −− | ++ | −− |
| Coons' agar | | | | ++ |
| Richards' liquid | −− | | | |
| Carrot plug / Potato plug | −− | −− | −− | −− |
| Nutrient agar | | | | ++ |

## TABLE II

GROWTH AND PIGMENTATION OF PARENT AND VARIANT STRAINS OF *CLADOSPORIUM FULVUM* ON SEVERAL MEDIA

| | PARENT | | | | | VARIANT | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Growth | Spore product | Variations | Color | | Growth | Spore product | Color | |
| | | | | Surface | Through medium | | | Surface | Through medium |
| Corn meal agar | ++ | +++ | − | Buckthorn-brown | Dark livid purple | ++ | −− | White | Astor purple |
| Corn meal flask | +++ | +++ | + | Dresden brown | | ++ | −− | White | |
| Oat meal agar | +++ | +++ | + | Metal bronze | Raisin-black | ++ | −− | White | Burnt-lake |
| Prune juice agar | +++ | +++ | + | Argus brown | Raisin-black | ++ | −− | Pale pinkish-buff | Dusky dull violet |
| Nutrient agar | +++ | +++ | − | Deep grayish-olive | Chaetura black | ++ | −− | White | Vinaceous |
| Rice flask | +++ | +++ | + | Brussels brown | Dusky olive-green | + | −− | White-shiny | |
| Carrot plug | +++ | +++ | − | Saccardo-umber | Dark | | | | |
| Coons' synthetic agar | +++ | +++ | − | Brussels brown | − | +++ | −− | White | |
| Synthetic agar 2 | +++ | +++ | + | Benzo-brown | Dusky purplish-grey | ++ | −− | White | Citrine |
| Czapeck synthetic agar | +++ | +++ | + | Deep olive-grey | Vinaceous-grey | ++ | −− | White | Dark heliotrope-grey |
| Shive's best synthetic agar | +++ | +++ | + | Buffy-citrine | Mumy-brown | ++ | −− | White | Hessian brown |
| Lima bean agar | +++ | +++ | + | Mouse-grey | Olivaceous-black | ++ | −− | White | Hessian brown |
| Tomato stems | +++ | +++ | − | Brownish-olive | Purple hyphae | ++ | −− | White | |

TABLE III

ARRANGEMENT OF CULTURES ACCORDING TO TRIANGLE SYSTEM

Figures represent quantities of M/5 chemicals

cc. M/5
Maltose per 100 cc.
1st figure

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7311 oo | | | | | | |
| | | | 6321 oo | | | 6411 oo | | | | |
| | | 5331 oo | | | 5421 oo | | | 5511 oo | | |
| | 4341 oo | | | 4431 oo | | | 4521 oo | | | 4611 oo |
| 3351 oo | | | 3441 oo | | | 3531 oo | | | 3621 oo | | | 3711 oo |

cc. M/5
Asparagin per 100 cc.
3d figure

cc. M/5
Potassium acid phosphate
per 100 cc.
2d figure

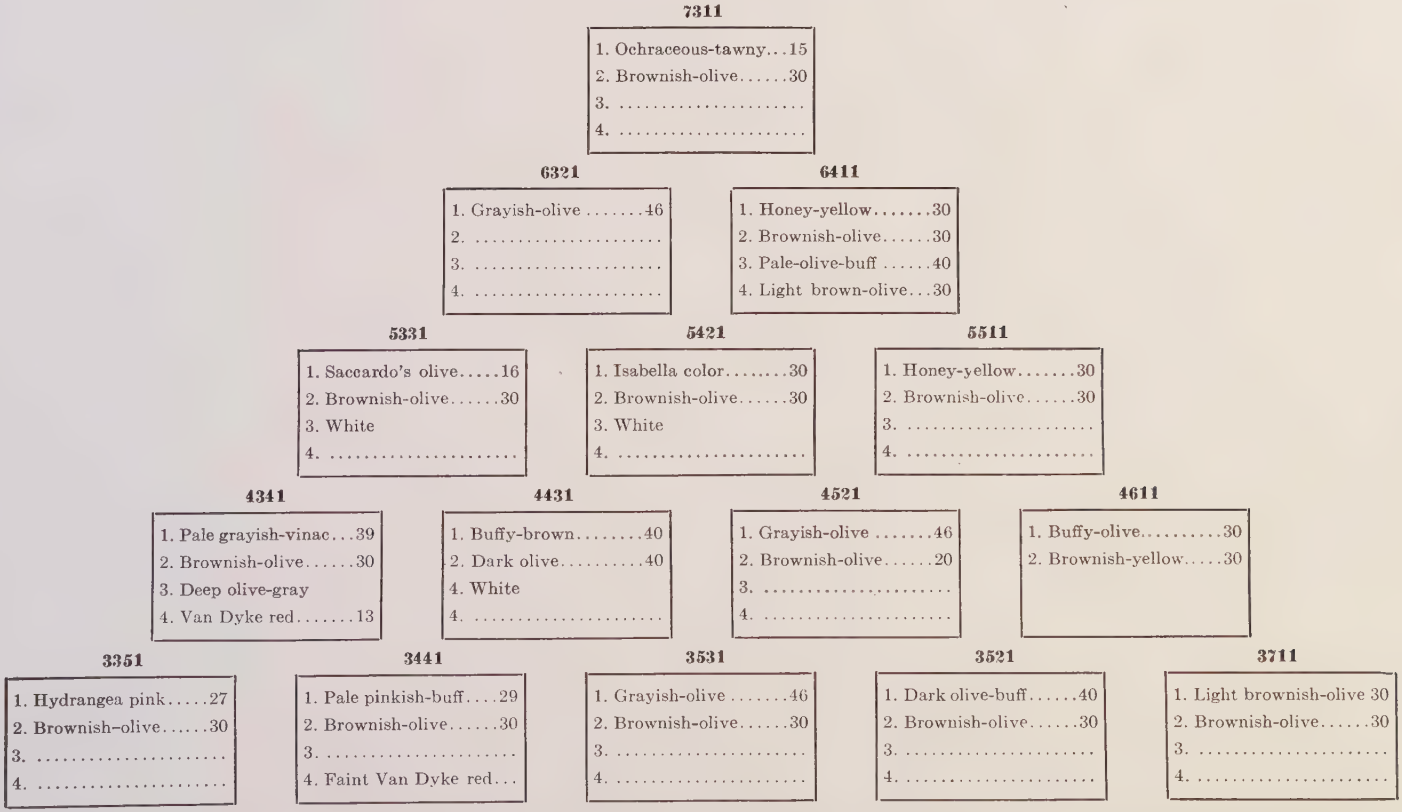
## TABLE IV

WEIGHTS OF *COLLETOTRICHUM LINDEMUTHIANUM* WHEN GROWN ON LIQUID COONS' MEDIUM VARIED ACCORDING TO THE TRIANGULAR SYSTEM, TOGETHER WITH A DESCRIPTION OF THE CULTURES

| MEDIUM | 1st Ser. mgs. | 2d Ser. mgs. | Average mgs. | DESCRIPTION |
|---|---|---|---|---|
| 7311 | 17.30 | 23.00 | 21.10 | Abundant growth, submerged mycelium dirty white, a ring of Natal brown adhering to the glass on the surface of the medium |
| 6321 | 9.9 | 9.0 | 9.4 | Wide blackish-brown ring around the edge, with black small sclerotium-like formations scattered through it. Submerged mycelium white |
| 6411 | 15.5 | 25.8 | 20.2 | No ring, no sclerotia, white mycelium, Royal-brown patches on the surface |
| 5331 | .8 | 13.5 | 6.3 | Abundant white mycelium. Concentrically arranged sclerotia on the surface. Narrow, black ring discontinuous |
| 5421 | 4.7 | 7.1 | 5.9 | Mycelium brownish. Concentrically arranged sclerotia on surface. Discontinuous black ring |
| 5511 | 10.1 | 10.0 | 10.0 | Mycelium pale brown. Ring indefinite |
| 4341 | 4.7 | 12.8 | 8.7 | Mycelium pure white. Discontinuous, loose black ring |
| 4431 | 4.0 | 6.3 | 5.1 | Mycelium nearly white. Wide, compact, blackish-brown, discontinuous ring |
| 4521 | 5.9 | 4.2 | 5.0 | Mycelium dirty white. Black, compact 1 cm. in diameter patches on the surface |
| 4611 | 2.7 | 6.3 | 4.5 | Mycelium brownish. Indefinite ring brown with sclerotia |
| 3351 | 2.0 | 11.0 | 6.5 | White mycelium. Thin ring with sclerotia |
| 3441 | 6.4 | 2.1 | 4.2 | Mycelium nearly white. Thin ring with sclerotia |
| 3531 | 2.0 | 4.8 | 3.3 | Mycelium brown. Thick brownish ring |
| 3621 | 3.0 | 4.0 | 3.5 | Mycelium brown, ring indefinite, sclerotia |
| 3711 | ooo | 2.9 | 2.9 | Mycelium brown, ring indefinite, sclerotia |

TABLE V. Color Variation of *Cladosporium fulvum* (Parent Strain) grown on Coons' Medium Varied in Composition according to the Triangular System

Sugar (Maltose) 1st Figure




**1.** Surface color
**2.** Color of submerged growth
**3.** Color variation on surface
**4.** Color diffused through the medium

TABLE VI. Color Variation of *Cladosporium fulvum* (Variant Form) grown on Coons' Medium Varied in Composition according to the Triangular System

Sugar (Maltose) 1st Figure

**7311**

1. Cream color.....16
2. Buckthorn-brown...15 (on top of slant)
3. .....
4. Brownish-olive.....30

**6321**

1. Buffy-brown.....40
2. White
3. Fawn.....40
4. .....

**6411**

1. Tillent buff.....40
2. .....
3. .....
4. Dusky olive-gray....41

**5331**

1. White
2. Cameo pink.....26
3. Deep vinaceous....27
4. .....

**5421**

1. Seashell-pink.....14
2. White
3. Warm sepia.....29
4. Mars yellow.....3

**5511**

1. White
2. Pale olive-buff.....40
3. Brownish-olive.....30
4. .....

**4341**

1. White
2. Pale lilac .....37
3. Mars violet.....38
4. Ochre red.....27

**4431**

1. White
2. .....
3. Vernonia purple.....36
4. .....

**4521**

1. White
2. .....
3. Cinnamon-brown
4. .....

**4611**

1. White
2. .....
3. Light brown-olive...30
4. Brownish-olive.....30

**3351**

1. White
2. Dark vinaceous-purple 36
3. Dark olive .....40
4. .....

Asparagin, 3rd figure

**3441**

1. White
2. Pale lilac.....37
3. Vinaceous-purple....38
4. .....

**1.** Surface color
**2.** Exception or tinge

**3531**

1. White
2. Pale lilac.....37
3. Mars violet
4. .....

**3.** Color of colony as seen through the slant
**4.** Color of the submerged growth

**3521**

1. White
2. .....
3. Corinthian purple...38
4. .....

**3711**

1. White
2. .....
3. Brownish-olive.....30
4. Brown-olive.....30

Phosphorus-potassium, 2d figure

## TABLE VII

### Titration of Richards' and Coons' Media

Centimeters of acid or alkali and water to be added to 25 cc. of double strength medium to obtain a series of media of varying pH and proper concentration of nutrients

| pH | cc. HCl | Normality | cc. NaOH | Normality | cc. $H_2O$ | Volume |
|---|---|---|---|---|---|---|
| Richards' | | | | | | |
| 2.0 | 11 | N/20 | ** | ** | 14 | 50 |
| 2.8 | 7 | N/50 | ** | ** | 18 | 50 |
| 3.7 | 1.5 | " | ** | ** | 23.5 | 50 |
| 4.8 | .25 | " | ** | ** | 24.75 | 50 |
| 5.0 | ** | ** | ** | ** | 25 | 50 |
| 5.8 | ** | ** | .5 | N/30 | 24.5 | 50 |
| 6.4 | ** | ** | 1.0 | " | 24 | 50 |
| 7.0 | ** | ** | 2.5 | " | 22.5 | 50 |
| 7.6 | ** | ** | 4.0 | " | 21 | 50 |
| 8.4 | ** | ** | 6.0 | " | 19 | 50 |
| Coons' | | | | | | |
| 2.4 | 20 | N/50 | ** | ** | 5 | 50 |
| 2.8 | 8 | " | ** | ** | 17 | 50 |
| 3.2 | 4 | " | ** | ** | 21 | 50 |
| 3.8 | 1.5 | " | ** | ** | 23.5 | 50 |
| 4.2 | .5 | " | ** | ** | 24.5 | 50 |
| 5.0 | ** | ** | ** | ** | 25 | 50 |
| 5.6 | ** | ** | .5 | N/20 | 24.5 | 50 |
| 6.4 | ** | ** | 2.5 | " | 22.5 | 50 |
| 7.0 | ** | ** | 5.5 | " | 19.5 | 50 |
| 7.6 | ** | ** | 7.5 | " | 17.5 | 50 |
| 8.4 | ** | ** | 9.5 | " | 15.5 | 50 |

## TABLE VIII

CHANGES IN UNINOCULATED MEDIA AFTER ONE AND ONE-HALF MONTHS

| Coons' Medium + Indicator | | | Richards' Medium + Indicator | | |
|---|---|---|---|---|---|
| | Start | Final | Indicator | Start | Final | Indicator |
| T.B. | 2.4* | 2.4 | T.B. | 2 | 2 | |
| T.B. | 2.4 | 2.4 | T.B. | 2 | | |
| T.B. | 2.8 | 2.8 | T.B. | 2.8 | | |
| T.B. | 2.8 | | | 2.8 | | |
| BPB | 3.2 | 3.2 | BPB | 3.7 | | |
| BPB | 3.2 | 3.2 | BPB | 3.7 | 3.7 | |
| BPB | 3.8 | 3.8 | | 4.8 | 4.8 | |
| BPB | 3.8 | | | 4.8 | 4.8 | |
| MR | 4.2 | | | 5.0 | 5.0 | |
| MR | 4.2 | | | 5.0 | 5.0 | |
| | 5.0 | 5.0 | MR | 5.8 | | |
| | 5.0 | | | 5.8 | 5.6 | BCP |
| | 5.6 | Faded | MR | 6.4 | | |
| | 5.6 | Faded | MR | 6.4 | | |
| | 6.4 | 6.4 | BTB | 7.0 | 6.4 | BTB |
| | 6.4 | | | 7.0 | 7.0 | BTB |
| | 7.0 | | | 7.6 | | |
| | 7.0 | | | 7.6 | Approx. 6.6 | more acid than PR range |
| | | | | 8.4 | | |
| | | | | 8.4 | 6.6 | BTB |
| | 8.4 | 8.4 | T.B. | | | |
| | 8.4 | | | | | |

* Initials refer to standard Clark and Lubs indicators

## TABLE IX

COMPARISON OF THE TWO STRAINS OF *CLADOSPORIUM FULVUM* IN COONS' MEDIUM OF VARYING HYDROGEN ION CONCENTRATION: CULTURES IN TEST TUBES

| PARENT FORM | | | | | VARIANT FORM | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Initial pH | Growth after 1½ mos. | Color after 1½ mos. | pH after 12 da. | pH after 1½ mos. | Initial pH | Growth after 1½ mos. | Color after 1½ mos. | pH after 12 da. | pH after 1½ mos. |
| 2.4 | ± | (Merely starting) | 2.4 | 2.4 | 2.4 | ± | (Merely starting) | 2.4 | 2.4 |
| | ± | " | | 2.4 | | ± | " | | 2.4 |
| 2.8 | + | Olive-grey | 2.8 | 2.6 | 2.8 | + | Bluish gray-green | | 3.0 |
| | + | " " | | 2.8 | | + | " " | | 3.4 |
| 3.2 | ++ | Warm buff | | 3.2 | 3.2 | ++ | Light buff | 3.2 | 3.4 |
| | ++ | " " | | 3.2 | | ++ | " " | | 3.4 |
| 3.8 | +++ | Tawny | 3.6 | 4.0 | 3.8 | ++ | Light buff | 3.6 | 4 |
| | +++ | " | | 4.0 | | ++ | " " | | 4.2 |
| 4.2 | ++++ | Buckthorn-brown * | 4.2 | 4.6 | 4.2 | +++ | Dark (submerged) | 4.2 | 4.6 |
| | ++++ | Buckthorn-brown | | 4.4 | | +++ | " " | | 4.6 |
| 5.0 | ++++ | Buckthorn-brown † | 5.0 | 5.2 | 5.0 | ++ | Light buff | 5.0 | 4.8 |
| | ++++ | Buckthorn-brown † | | 5.2 | | ++ | " " | | 4.8 |
| 5.6 | +++ | Buckthorn-brown | 5.6 | 5.6 | 5.6 | +++ | Light buff | 5.6 | 5.4 |
| | +++ | " " | | 5.6 | | +++ | " " | | 5.4 |
| 6.4 | ++ | Buckthorn-brown ‡ | 6.4 | 6.2 | 6.4 | ++ | Light buff | 6.4 | 6.2 |
| | ++ | " " | | 6.4 | | ++ | " " | | 6.2 |
| 7.0 | | | | | 7.0 | | | | |
| 7.6 | ++ | Buckthorn-brown | 7.2 | 7.2 | 7.6 | ++ | Light tan | 7.2 | 7.2 |
| | | " " | | 7.2 | | | | | |
| 8.4 | + | Russet-vinaceous | | 7.4 | 8.4 | ++ | Pinkish-white | 8.4 | 6.8 |
| | | | | | | ++ | " " | | 7.6 |

* 1 "White island" † 4 "White islands" ‡ 2 "White islands"

## TABLÆ X

COMPARISON OF THE TWO STRAINS OF *CLADOSPORIUM FULVUM* ON RICHARDS' MEDIUM OF VARYING HYDROGEN ION CONCENTRATION: CULTURES IN TEST TUBES

| PARENT FORM | | | | | VARIANT FORM | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Initial pH | Growth after 1½ mos. | Color | pH after 12 days | pH after 1½ mos. | Initial pH | Growth after 1½ mos. | Color | pH after 12 days | pH after 1½ mos. |
| 2.0 | 0 | | — | 2.0 | 2.0 | 0 | | 2.0 | |
| | 0 | | | 2.0 | | 0 | | 2.0 | |
| 2.8 | + | Light olive-gray | 2.8 | 2.5 | 2.8 | + | (Submerged) | 2.8 | 2.5 |
| | + | " | 2.8 | 2.5 | | + | Light gull-gray | | 2.5 |
| 3.7 | + | Gray | 3.5 | 3.2 | 3.7 | | | | |
| | + | Light olive-gray | 3.5 | 2.4 | | + | Pale olive-gray | 3.5 | 2.8 |
| 4.8 | ++ | Tea-green | 4.6 | | 4.8 | ++ | Ivory-yellow | 4.6 | 2.8 |
| | ++ | " | 4.6 | 2.7 | | ++ | Light grayish-olive | | 2.8 |
| 5.0 | + | Mineral-gray | 4.8 | 2.6 | 5.0 | ++ | Olive-buff | 4.8 | 2.6 |
| | + | " " | 4.8 | | | ++ | Vinaceous-buff | | 2.4 |
| 5.8 | ++ | Tea-Green | 5.4 | 2.6 | 5.8 | +++ | Ochraceous-tawny | 5.4 | 2.8 |
| | ++ | " " | 5.4 | 2.6 | | +++ | " " | 5.4 | 2.4 |
| 6.4 | ++ | Olive-lake | | 3.6 | 6.4 | ++++ | Gray | | 2.2 |
| | ++ | " " | | 2.4 | | | | | 2.4 |
| 7.0 | ++ | Light olive-gray | 6.6 | 3.2 | 7.0 | ++ | Pale olive-buff | 6.6 | 2.4 |
| | ++ | Olive-gray | 6.6 | 2.6 | | ++ | " " | 6.6 | 2.5 |
| 7.6 | ++ | Olive-gray | 7.0 | 2.6 | 7.6 | +++ | Pinkish-buff | 7.0 | 2.4 |
| | ++ | Olive-gray | 7.0 | 2.6 | 7 | +++ | " " | | 2.4 |
| 8.4 | ++ | Olive-gray | | 4.1 | 8.4 | + | Pinkish-buff | | 4.4 |
| | ++ | Olive | | 2.5 | | + | " " | | 3.5 |

## TABLE XI

COMPARISON OF THE TWO STRAINS OF *CLADOSPORIUM FULVUM* ON COONS' AND RICHARDS' MEDIA OF VARYING HYDROGEN ION CONCENTRATION: CULTURES IN PREPARATION DISHES WITH FILTER PAPER CONES

RICHARDS' MEDIUM

| PARENT FORM | | | | VARIANT FORM | | | |
|---|---|---|---|---|---|---|---|
| pH | Growth | Color | Spores | pH | Growth | Color | Spores |
| 2. | −<br>− | | | 2. | | | − |
| 2.8 | Contam.<br>+ | Dark gray-green | ± | 2.8 | +<br>+ | Greenish<br>" | −<br>− |
| 3.7 | Contam.<br>++ | Dark gray-green | + | 3.7 | Contam.<br>+ | Tan | − |
| 4.8 | +<br>++ | Blue-green<br>Greenish | + | 4.8 | +<br>+ | Tan<br>" | −<br>− |
| 5.0 | +<br>+ | Olive-green<br>" " | | 5.0 | Contam.<br>" | | |
| 5.8 | +<br>+ | Olive-green<br>Greenish-black | + | 5.8 | +<br>+ | Pale vinaceous-lilac<br>Growth at edge greenish | −<br>− |
| 6.4 | ++++<br>++++ | Olive-green<br>" " | +<br>+ | 6.4 | ++<br>Contam. | Buff | − |
| 7.0 | +++<br>Contam. | Olive-green | + | 7.0 | ++<br>++ | Buff<br>" | −<br>− |
| 7.6 | +++<br>+++ | Blue-green<br>" " | +<br>+ | 7.6 | Contam.<br>Contam. | | |
| 8.4 | +++<br>Contam. | Blue-green | + | 8.4 | ++++<br>++++ | Dark-gray<br>" " | −<br>− |

## TABLE XI* (*Continued*)

Coons' Medium

| Parent Form | | | | Variant Form | | | |
|---|---|---|---|---|---|---|---|
| pH | Growth | Color | Spores | pH | Growth | Color | Spores |
| 2.4 | –<br>+ | <br>Grayish | <br>+ | 2.4 | ++++<br>++++ | Greenish<br>" | –<br>– |
| 2.8 | +<br>+ | Dark greenish<br>Dark green | +<br>+ | 2.8 | ++++<br>++++ | Grayish-black<br>" " | –<br>– |
| 3.2 | ++++<br>++++ | Light buff<br>" " | +<br>+ | 3.2 | ++++<br>++++ | Grayish-black<br>" " | –<br>– |
| 3.8 | +++<br>+++ | Dark purple<br>" " XX | +<br>+ | 3.8 | ++<br>++ | Light vinaceous-lilac<br>Light vinaceous-lilac | –<br>– |
| 4.2 | +++<br>+++ | Dark purple<br>" " X | +<br>+ | 4.2 | ++<br>+ | Light vinaceous-lilac<br>White, orig. inoc. buff | –<br>– |
| 5.0 | +++<br>+++ | " " XX<br>" " | +<br>+ | 5.0 | ++<br>+++ | Pale vinac.<br>" " | –<br>– |
| 5.6 | +++<br>+++ | " "<br>" " | +<br>+ | 5.6 | +++<br>Contam. | " " | – |
| 6.4 | ++++<br>++++ | Purple X<br>Purplish-brown | +<br>+ | 6.4 | ++++<br>+++ | Light vinaceous-lilac<br>Buff to creamy<br>" " " | –<br>– |
| 7.0 | ++++<br>++++ | Purplish-brown X<br>" " | +<br>+ | 7.0 | ++++<br>Contam. | Deep vinaceous-lavender | – |
| 7.6 | ++++<br>++++ | " " X<br>" " XX | +<br>+ | 7.6 | ++<br>++ | Deep vinaceous-purple<br>" " " | –<br>– |
| 8.4 | +<br>+ | Purplish<br>" XXX | <br>+ | 8.4 | ++<br>Contam. | " " " | – |

X – White island

## TABLE XII

COMPARISON OF THE TWO STRAINS OF *COLLETOTRICHUM LINDEMUTHIANUM*, STRAIN II, WHEN GROWN ON COONS' MEDIUM OF VARYING CONCENTRATIONS: CULTURES IN TEST TUBES

| PARENT FORM | | | | | VARIANT FORM | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Initial pH | Relative growth after 1½ mos. | Color | Acervuli with spores | pH after 1½ mos. | Initial pH | Relative growth after 1½ mos. | Color | Acervuli with spores | pH after 1½ mos. |
| 2.4 | 0 | | | 2.4 | 2.4 | 0 | | | 2.4 |
| | 0 | | | 2.4 | | 0 | | | 2.4 |
| 2.8 | | Black | | | 2.8 | | White * | 0 | 3.2 |
| | +++ | | +++ | 2.8 | | + | | 0 | 3.2 |
| 3.2 | +++ | Black | +++ | 3.6 | 3.2 | + | White * | 0 | 3.6 |
| | +++ | " | +++ | 3.6 | | + | White * | 0 | 3.5 |
| 3.8 | +++ | " | +++ | 4.4 | 3.8 | − | | − | − |
| | +++ | " | +++ | 4.6 | | ++ | White * | 0 | 4.6 |
| 4.2 | +++ | " | +++ | 4.6 | 4.2 | ++ | White * | 0 | 4.6 |
| | +++ | " | +++ | 4.6 | | ++ | White * | 0 | 4.6 |
| 5.0 | +++ | " | +++ | 5.4 | 5.0 | + | White * | 0 | 4.4 |
| | 0 | | 0 | 5.0 | | +++ | White * | 0 | 5.2 |
| 5.6 | 0 | | 0 | 5.5 | 5.6 | + | White * | 0 | 4.8 |
| | +++ | Black | +++ | 6.6 | | +++ | White * | 0 | 5.4 |
| 6.4 | +++ | " | +++ | 6.2 | 6.4 | ++ | White * | 0 | 6. |
| | +++ | " | +++ | 6.2 | | − | | | |
| 7.0 | | | | | 7.0 | | | | |
| 7.6 | | | | | 7.6 | | | | |
| 8.4 | +++ | Black | +++ | 7.6 | 8.4 | | | | |
| | +++ | | +++ | 7.2 | | ++ | White * | 0 | 7.2 |

* Submerged

## TABLE XIII

COMPARISON OF THE TWO STRAINS OF *COLLETOTRICHUM LINDEMUTHIANUM* WHEN GROWN ON RICHARDS' MEDIUM OF VARYING HYDROGEN ION CONCENTRATIONS: CULTURES IN TEST TUBES

| PARENT FORM | | | | | VARIANT FORM | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Initial pH | Relative growth after 1½ mos. | Color | Acervuli with spores | pH after 1½ mos. | Initial pH | Relative growth after 1½ mos. | Color | Acervuli with spores | pH after 1½ mos. |
| 2. | 0 | | | | 2. | ± | | 0 | |
| | 0 | | | | | 0 | | 0 | |
| 2.8 | + | Not recorded | 0 | 2.6 | 2.8 | + | | 0 | 2.8 |
| | 0 | | | 2.6 | | + | | 0 | 2.8 |
| 3.7 | +++ | Cream | + | 4.4 | 3.7 | ++ | White * | 0 | 4.4 |
| | +++ | " | + | 5.8 | | ++ | White | 0 | 5.1 |
| 4.8 | ++ | White * | 0 | 4.8 | 4.8 | − | | | |
| | +++ | Shell-pink | + | 5.7 | | +++ | White * | 0 | 5.2 |
| 5.0 | ++ | White * | + | 4.8 | 5.0 | ++ | White * | 0 | 4.6 |
| | +++ | Shell-pink | +++ | 6.6 | | +++ | " | 0 | 3.6 |
| 5.8 | +++ | Shell-pink | ++ | 6.4 | 5.8 | ++ | White * | 0 | 4.6 |
| | +++ | Shell-pink | +++ | 6.4 | | | | | |
| 6.4 | +++ | Shell-pink, but blk. with acervuli | +++ | 6.3 | 6.4 | ++ | White * | 0 | 5.4 |
| | +++ | " " | +++ | 6.3 | | ++ | " | 0 | 5.0 |
| 7.0 | +++ | " " | +++ | 6.2 | 7.0 | ++ | " | 0 | 5.8 |
| | +++ | " " | +++ | 6.4 | | +++ | " | 0 | 4.9 |
| 7.6 | ++ | Shell-pink | + | 5.9 | 7.6 | | " | | |
| | ++ | " | 0 | 6.0 | | ++ | White * | 0 | 5.8 |
| 8.4 | ++ | Shell-pink | +++ | 6.6 | 8.4 | + | " | 0 | 6.5 |
| | ++ | " " | +++ | 6.2 | | + | " | 0 | 6.2 |

* Submerged

## TABLE XIV

Comparison of Two Strains of *Colletotrichum lindemuthianum*, Strain II, When Grown on Richards' and Coons' Media of Varying Hydrogen Ion Concentration: Cultures in Preparation Dishes with Filter Paper Cones

Richards' Solution

| Parent Form | | | | Variant Form | | | |
|---|---|---|---|---|---|---|---|
| pH | Growth | Color | Spores | pH | Growth | Color | Spores |
| 2. | –<br>– | | | 2. | –<br>– | | |
| 2.8 | +++<br>+++ | Black<br>" | +<br>+ | 2.8 | –<br>– | | |
| 3.7 | ++++<br>++++ | "<br>" | +<br>+ | 3.7 | Contam.<br>" | | |
| 4.8 | ++++<br>++++ | "<br>" | +<br>+ | 4.8 | Contam.<br>+ | | |
| 5. | Contam.<br>++++ | <br>Black | <br>+ | 5. | Contam.<br>" | | |
| 5.8 | ++++<br>Contam. | " | + | 5.8 | Contam.<br>+ | <br>Creamy | <br>– |
| 6.4 | ++++<br>++++ | Black<br>" | –<br>– | 6.4 | ++++<br>Contam. | Cream | – |
| 7. | ++++<br>Contam. | " | – | 7. | Contam.<br>++++ | <br>Cream | <br>– |
| 7.6 | ++++<br>++++ | "<br>" | +<br>+ | 7.6 | +++<br>+++ | "<br>" | –<br>– |
| 8.4 | ++++<br>Contam. | " | + | 8.4 | +++<br>+++ | Cream<br>" | –<br>– |

## TABLE XIV (*Continued*)

COONS' SYNTHETIC SOLUTION

| PARENT FORM | | | | VARIANT FORM | | | |
|---|---|---|---|---|---|---|---|
| pH | Growth | Color | Spores | pH | Growth | Color | Spores |
| 2.4 | +<br>Contam. | | − | 2.4 | +<br>+ | Cream<br>" | −<br>− |
| 2.8 | ++<br>++++ | Greenish-black<br>" " | −<br>+ | 2.8 | ++++<br>++++ | Dark gray<br>" " | −<br>− |
| 3.2 | ++++<br>++++ | Black<br>" | +<br>+ | 3.2 | ++++<br>++++ | Grayish-black<br>Jet black in places | −<br>− |
| 3.8 | ++++<br>++++ | "<br>" | +<br>+ | 3.8 | ++++<br>++++ | Jet black in places<br>" " | −<br>− |
| 4.2 | ++++<br>++++ | Black<br>" | +<br>+ | 4.2 | +++<br>++++ | Red-brown<br>Black | −<br>− |
| 5. | ++++<br>++++ | "<br>" | +<br>+ | 5. | ++<br>++ | Black<br>" | −<br>− |
| 5.6 | +++++<br>+++++ | "<br>" | +<br>+ | 5.6<br>5. | ++<br>++ | "<br>" | −<br>− |
| 6.4 | ++++<br>++++ | Black<br>" | +<br>+ | 6.4 | +<br>Contam. | Black | − |
| 7. | ++++<br>++++ | "<br>" | +<br>+ | 7. | +++<br>+++ | Black<br>" | −<br>− |
| 7.6 | ++++<br>++++ | "<br>" | +<br>+ | 7.6 | +++<br>Contam. | " | − |
| 8.4 | ++++<br>++++ | "<br>" | ++<br>++ | 8.4 | ++<br>++ | Black<br>" | −<br>− |

## TABLE XV

Effect of Temperature and Reaction on Color and Growth on the Parent and Variant Strains of *Cladosporium fulvum* grown on Modified Shive's Best Medium of Varying pH and Kept at Different Temperatures

Temperature 30–32° C.

No growth beyond the point of inoculation at which a slight weak growth was observed 54 days after the inoculation

Temperature 10° C.

No growth whatever

| Temperature 20–25° C. After 3 days | | | After 8 days | |
|---|---|---|---|---|
| | Diam. mm. | | Diam. mm. | |
| pH 4.0 | | | | |
| Parent | 3.0 | Slight growth, whitish | 6.5 | Surf. Light olive-green<br>Under. Red-brown |
| Variant | 2.5 | White | 5.5 | Surf. White<br>Under. Yellow-brown |
| pH 5.0 | | | | |
| Parent | 1.5 | Greenish-brown | 4.5 | Surf. Light olive-green<br>Under. Green |
| Variant | 2.0 | White | 4.0 | Surf. White<br>Under. Dark yellow-brown |
| pH 6.0 | | | | |
| Parent | 2.0 | Greenish-brown | 3.0 | Surf. Light olive-green<br>Under. Green |
| Variant | 3.0 | White | 4.5 | Surf. White<br>Under. Dark yellow-brown |
| pH 7.0 | | | | |
| Parent | 2.0 | Greenish-brown | 6.0 | Surf. Light olive-green<br>Under. Purple-brown |
| Variant | 2.5 | White | 4.5 | Surf. White<br>Under. Orange-brown |
| pH 8.0 | | | | |
| Parent | 2.5 | Greenish-brown | 5.5 | Surf. Light olive-green<br>Under. Purple, white edge |
| Variant | 3.0 | White | 5.0 | Surf. White<br>Under. Purple |

TABLE XV (*Continued*)

TEMPERATURE 20–25° C. After 54 days

| | Diam. mm. | |
|---|---|---|
| pH 4.0 | | |
| Parent | 10 | Surf. Brownish-olive 30 |
| | | Under. Dull greenish-black 47 |
| Variant | 20 | Surf. White center, clay color edge |
| | | Under. Hessian brown center, ochraceous-orange edge |
| pH 5.0 | | |
| Parent | 9 | Surf. Light brownish-olive 30 |
| | | Under. Dull greenish-black 47 |
| Variant | 20 | Surf. Pale yellow-orange |
| | | Under. Hazel 14 |
| pH 6.0 | | |
| Parent | 5 | Surf. Light brownish-olive 30 |
| | | Under. Dull greenish-black 47 |
| Variant | 15 | Surf. White center, ochraceous-buff edge |
| | | Under. Hazel 14 |
| pH 7.0 | | |
| Parent | 12 | Surf. Light brownish-olive 30 |
| | | Under. Dull greenish-black 47 |
| Variant | 7 | Surf. White-light ochraceous-buff |
| | | Under. Hessian brown |
| pH 8.0 | | |
| Parent | 6 | Surf. Light brownish-olive 30 |
| | | Under. Olivaceous greenish-black 47 |
| Variant | 12 | Surf. White-pale ochraceous-buff |
| | | Under. Hessian brown |

## EXPLANATIONS OF PLATES

PLATE VIII

FIG. 1. *Septoria apii* with "white island" (left)
*Cladosporium fulvum* with "white island" (right)

FIG. 2. *Colletotrichum lindemuthianum*, normal culture (right), contrasted with culture in which white variant is developing

PLATE IX

*Cladosporium fulvum*. Parent form, *A;* variant form, *B* (Camera lucida drawings)

PLATE X

*Septoria apii* growing upon various combinations of nutrients

PLATE XI

*Colletotrichum lindemuthianum*, Strain I, growing upon various combinations of nutrients

PLATE XII

*Colletotrichum lindemuthianum*, Strain II, growing upon various combinations of nutrients

PLATE XIII

*Colletotrichum lindemuthianum* grown in liquid media (various combinations) to determine relative growth (cf. Table IV)

PLATE XIV

*Cladosporium fulvum*, parent form, growing on various combinations of nutrients. "White islands" appearing in certain cultures. Grown in light

PLATE XV

*Cladosporium fulvum*, parent form. Same combinations as in Plate XIV, but grown in dark

PLATE XVI

*Cladosporium fulvum*, variant form, growing on various combinations of nutrients. Grown in light

PLATE XVII

Same as Plate XVI, but grown in dark

PLATE XVIII

FIG. 1. Tomato leaves (*a*, *b*) inoculated with parent form of *Cladosporium fulvum*. Check leaf at *c*.

FIG. 2. Tomato leaves (*a*, *b*) inoculated with variant form of *Cladosporium fulvum*. Check leaf at *c*.

PLATE VIII

FIG. 1

FIG. 2

PLATE IX

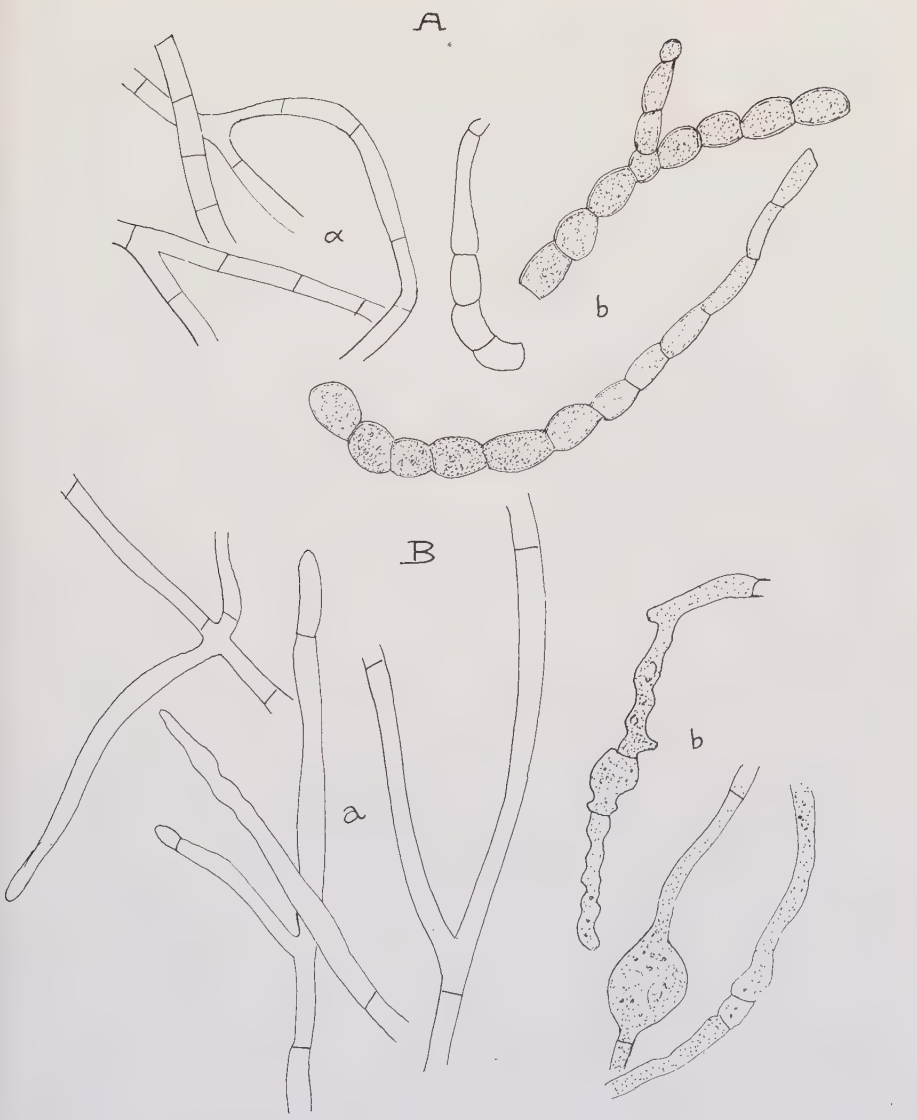


PLATE X

PLATE XI

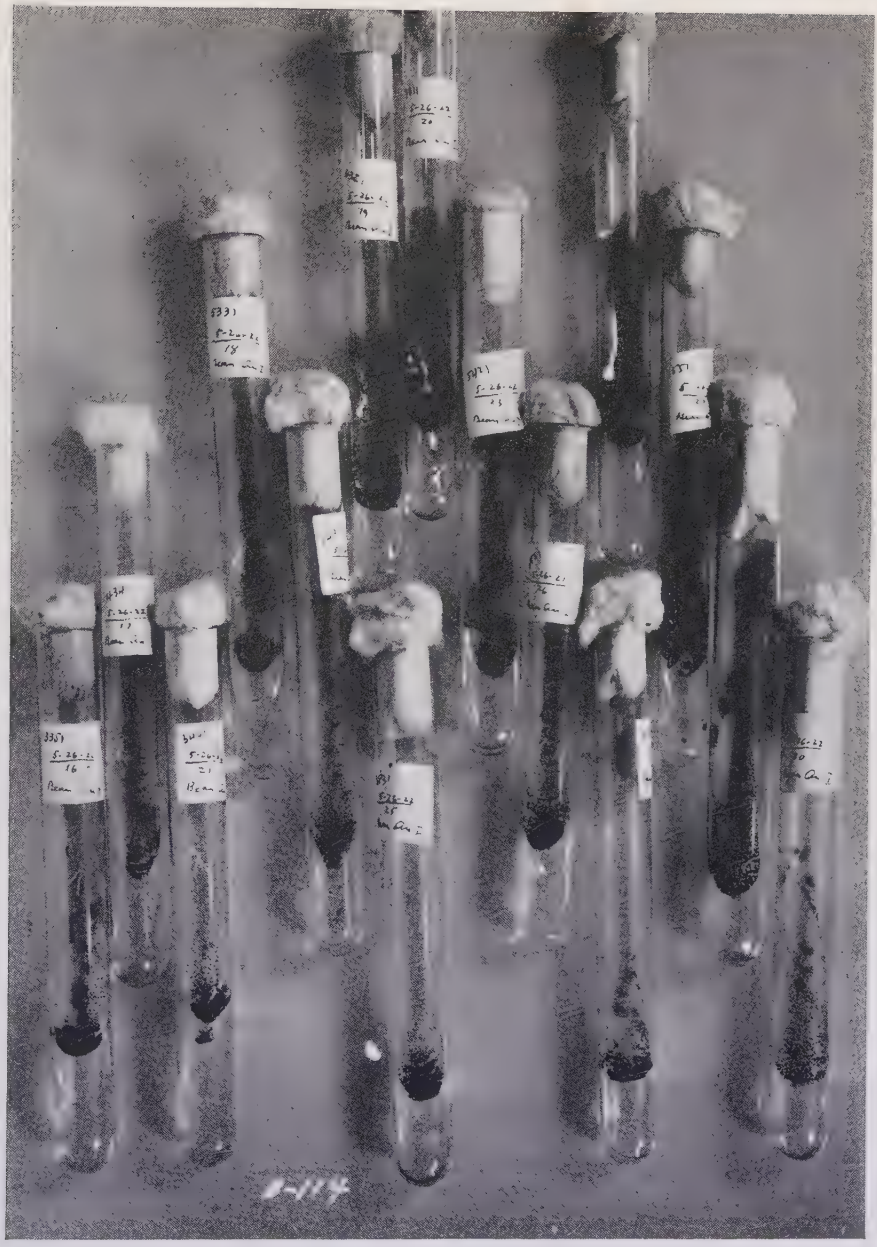
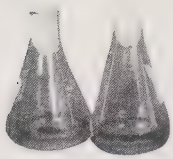


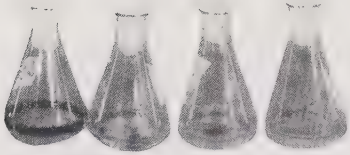
PLATE XII

# PLATE XIII

Maltose

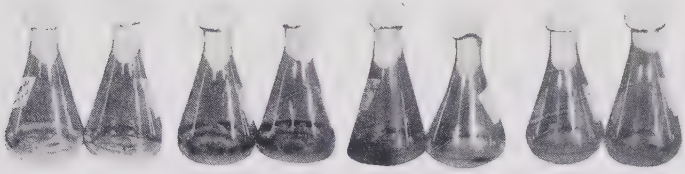


7311



6321 6411

5331 5421 5511



4341 4431 4521 4611

3351 3441 3531 3621 3711

Asparagin

$KH_2PO_4$

PLATE XIV

PLATE XV

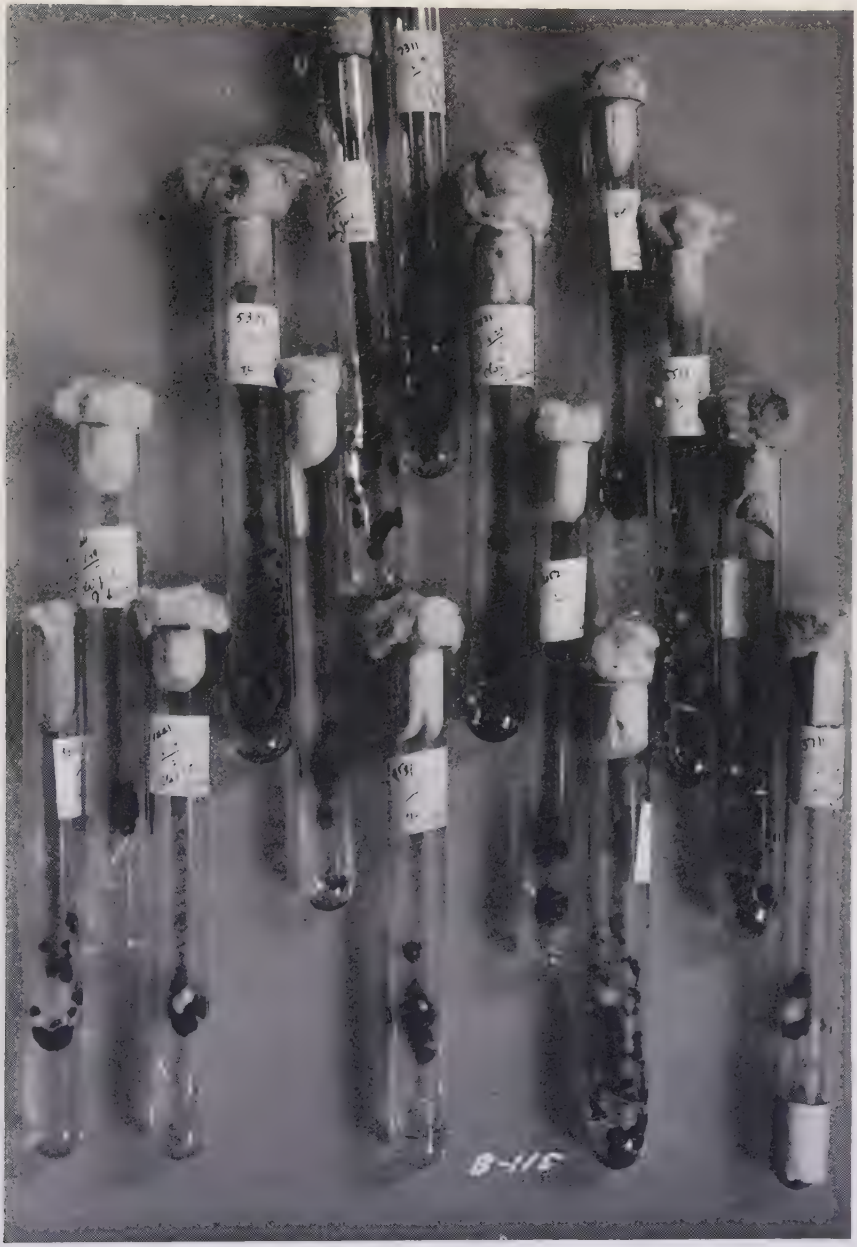


PLATE XVI

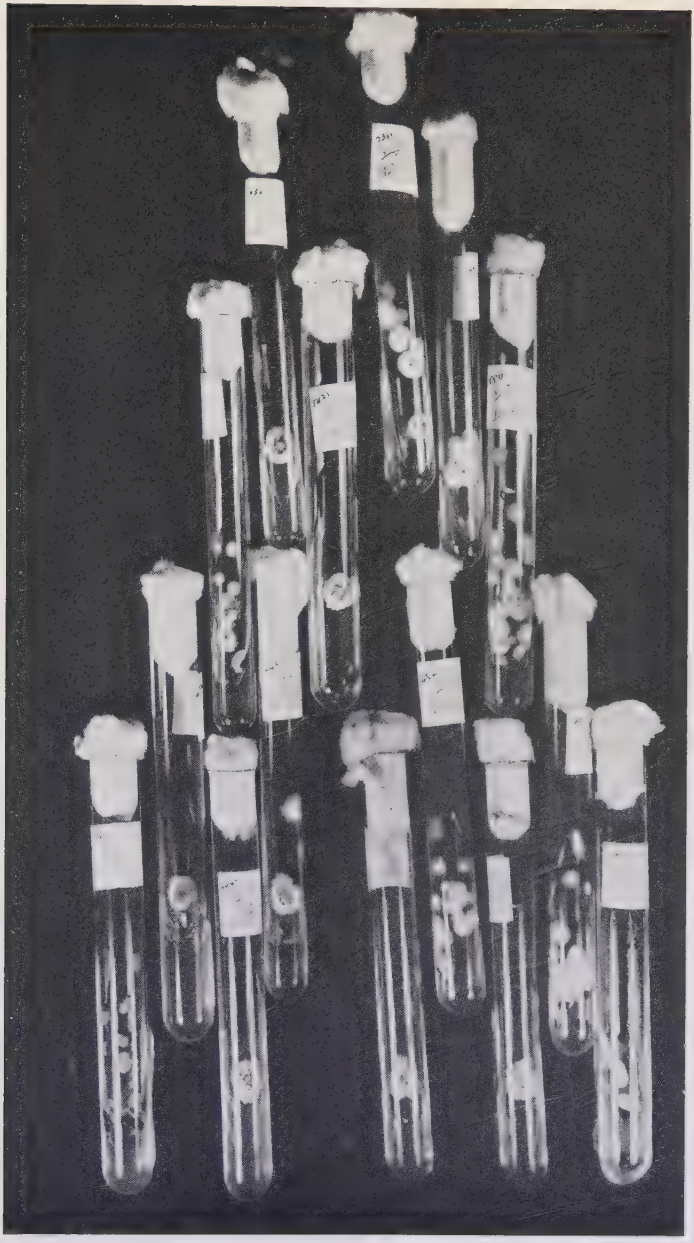


PLATE XVII

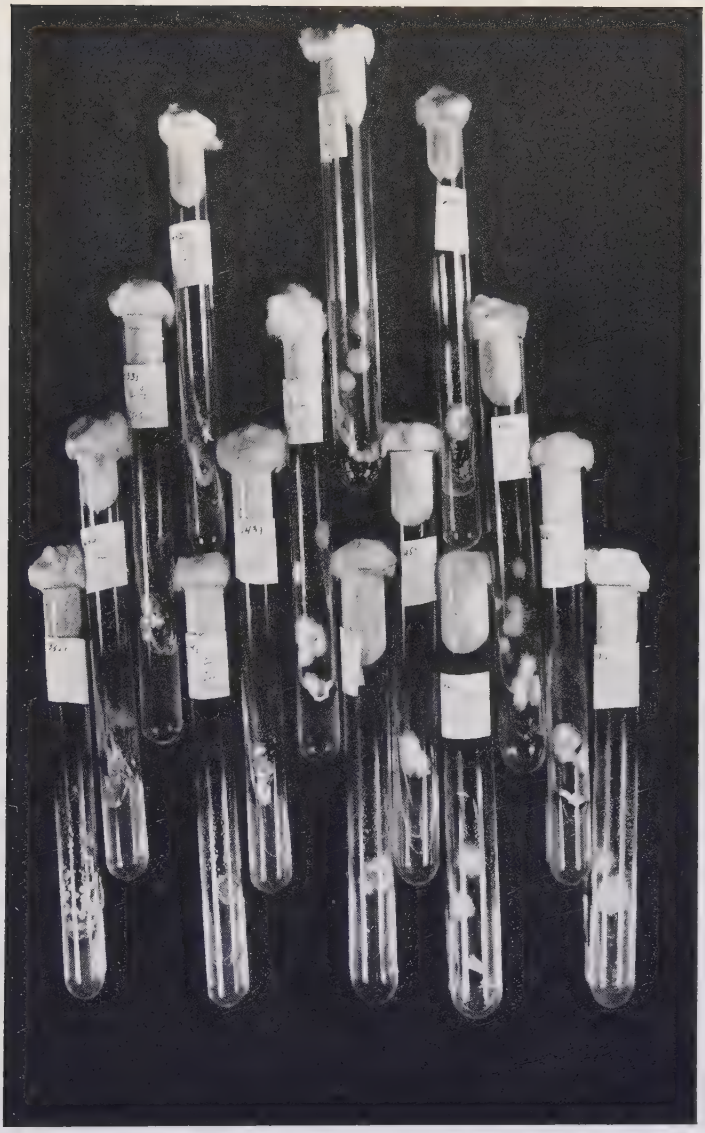


PLATE XVIII

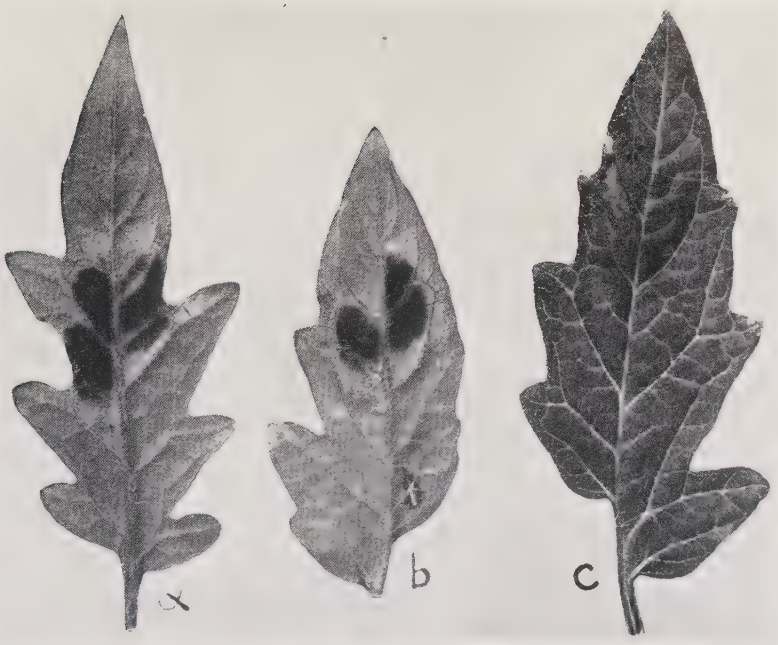



FIG. 1

FIG. 2

# PLANT DISTRIBUTION AS AFFECTED BY THE HYDROGEN ION CONCENTRATION OF THE SOIL*

FELIX G. GUSTAFSON

DURING the last ten years, that phase of plant ecology dealing with plant distribution and hydrogen ion concentration of the soil has received considerable attention. Even as early as 1910 Coville (6) pointed out that *Vaccinium corymbosum* grew together with *Cypripedium acaule* and *Azalea nudiflora* "in two kinds of situations — one a peat bog, the other a sandy well-drained, and often dry upland." He further pointed out that their occurrence in these two situations depends upon the acidity of the soil. Wherry (14) has published several papers on this subject, which are summarized in his paper in the *Annual Report of the Smithsonian Institution for 1920*. In these papers he has shown that plants grow in nature only when the H-ion concentration is within certain limits. Sometimes this range may be quite large, at other times very narrow. O. Arrhenius (2) has studied the "Skärs" around Stockholm, Sweden, and he finds that among the factors influencing plant distribution H-ion concentration plays a very important rôle. Carsten Olsen (9), working at the Carlsberg Laboratory in Copenhagen, Denmark, published in Danish in 1921, and in English in 1923, a paper dealing with plant distribution and growth as influenced by the free acidity of the soil. Atkins (4) in Ireland has also studied the relation between plant distribution and soil acidity. Braun-Blanquet (5) studying the vegetation of the Mediterranean found that the H-ion concentration seems

* Paper from the Department of Botany of the University of Michigan, No. 247.

to be the factor determining the distribution of the so-called calcicoles rather than lime. It is thus seen that several investigators in widely separated places have found that plants in nature are greatly influenced by the active acidity of the soil.

During the late summer of 1922, the writer spent two weeks on the southwest shore of Higgins Lake, Roscommon County, Michigan. Part of the time was spent in studying the flora of the immediate vicinity and a rather large number of the acid-loving Ericaceae, as well as other plants usually growing in acid soil, were found. In the summer of 1925 the same locality was visited a second time, and this time preparation was made to study the H-ion concentration of soils around the roots of some of these plants, especially the Ericaceae. Some studies of the soil reactions in which Ericaceae grew were made at different places, but it was soon found that a much more important problem presented itself in the plant distribution on a small area about 400 by 50 feet next to the lake. Here in a small area plants usually located in the most acid bogs as well as plants of neutral soil were found growing almost side by side. This seemed to disprove the idea that the H-ion concentration influenced plant distribution.

The H-ion concentration was determined colorimetrically. The indicators used were methyl red, brome cresol purple, phenol red and neutral red. The soil about the roots of the plants was obtained and placed in a vial to which well water of a pH 7.5–7.7 was added in a definite quantity. Preliminary tests were made to determine the length of time necessary to let the preparation stand before an equilibrium was established. It was found that after a lapse of ten minutes there was no change in the pH of the water in contact with the soil, and in all actual tests made the standard time was ten minutes. These determinations were made at once in the field. The water was decanted, the indicator added and the color compared with a chart.

The ground under investigation stretched along the shore for about 400 feet and may be divided into seven zones running side by side. Zones 3, 5 and 6 extend between two and three hundred feet in the middle of the four-hundred-foot strip along

the shore. Zone 1 was the bare sandy beach about 15 to 20 feet wide. The H-ion concentration of the sand was pH 8+, which was the same as that of the lake water.

Zone 2 was a narrow ridge just above Zone 1, about two to three feet high. This ridge has evidently been formed by the ice pushing the sand up during the spring of the year. The H-ion concentration was slightly less than pH 8. Plants found here were *Mentha arvensis* var. *canadensis, Solidago sp., Rosa sp., Hystrix patula, Equisetum sp., Smilacina stellaria, Elymus canadensis* and a few shrubs. The soil was composed entirely of sand.

Zone 3 was a depression a foot or two lower than the ridge. The soil was partly humus on top with sand beneath. The pH of the soil was 7.5–7.8. Here were found *Campanula apparinoides, Solidago sp., Apios tuberosa, Bromus sp., Spartina Michauxiana, Eupatorium purpureum, E. perfoliatum, Gentiana procera, Circium sp.* and *Rosa sp.*, also some unidentified grasses. The Solidago and Rosa were the same as found in Zone 2. The difference between Zones 2 and 3 lay in the larger amount of humus, greater moisture content and a slightly higher H-ion concentration of Zone 3 than of Zone 2. It is quite striking that the two zones have only two plants in common. Whether this difference in the plants is due to one factor or more is of course impossible to determine in this instance.

Zone 4 was a second ridge composed almost entirely of sand in the middle with a gradual increase in humus on the two sides. Near the south end there were two large trees of *Pinus strobus,* and under them the humus had accumulated to quite a depth. The H-ion concentration of the soil on the lake side of the ridge was pH 7.5–7.8, while on the opposite side it was pH 7.2–7.3. The second ridge was characterized by a very extensive growth of *Arctostaphylos Uva-ursi.* Besides this plant there were also *Fragaria sp., Campanula rotundifolia, Pyrola elliptica* (under the white pines), *Rosa sp., Prunella vulgaris, Anemone cylindrica, Rudbeckia hirta, Solidago sp., Maianthemum canadense, Smilacina stellaria, Melampyrum lineare, Bromus sp., Poa pratensis, Lactuca sp., Linnaea borealis,* and one unidentified species. Zone 4 contained *Rosa sp.* and *Solidago sp.* common to Zones 2 and 3, *Smi-*

*lacina stellaria*, also found in Zone 2, and *Bromus sp.* found in Zone 3; all others were different. The only difference in the soil of Zones 2 and 4 was that of actual acidity; both were sandy and of about equal moisture content.

Zone 5 was the transition ground between the second ridge and the second depression. This zone was broadest near the middle and extended for only about 200 feet in length. The soil was composed of humus on top with sand below; the amount of humus was approximately the same as in Zone 3, but it was somewhat drier and less compact. The H-ion concentration was between pH 4 and 4.5. The characteristic plants were *Gaultheria procumbens* and *Epigaea repens*. Others present were *Maianthemum canadense, Melampyrum lineare, Osmunda cinnamomea, Vaccinium pennsylvanicum, Chimaphila umbellata* and on the side near Zone 4 some *Fragaria sp.* The great increase in H-ion concentration of this zone, especially on the side toward the second depression, apparently enabled the three acidophile Ericaceae and the Osmunda to grow.

Zone 6 was a second depression, which in 1922 had considerable standing water in it, but was dry in 1925. Part of the area was covered with sphagnum, but a great deal was black muck grading into the humus and sand on both sides of the depression. The water squeezed from the sphagnum had a pH of 3–4, the muck in between the sphagnum had about the same acidity. The plants growing here were *Sphagnum sp., Polytrichum sp., Lycopodium obscurum, Chamaedaphne calyculata, Ledum groenlandicum, Rubus triflorus, Aspidium Thelypteris, Osmunda regalis* and an unknown sedge. Ledum and Chamaedaphne were few in number growing in the sphagnum.

Beyond the depression was an area similar to Zone 5 where grew *Epigaea repens, Gaultheria procumbens, Cypripedium acaule, Vaccinium pennsylvanicum, V. vacillans, Melampyrum lineare, Pteris aquilina* and *Maianthemum canadense.*

Beyond Zone 7 and extending into the woods were Pteris, the two Vaccinia, Gaultheria, Melampyrum, *Rhus toxicodendron, Cladonia rangeferina* and near the preceding zone an occasional Epigaea and Cypripedium.

Throughout this area described were shrubs and a few trees. Near the shore were *Thuja occidentalis, Cornus stolonifera, Alnus sp., Salix sp.*, a few *Pinus strobus, Acer rubrum, Betula alba* var. *papyrifera, Larix laricina, Populus tremuloides* and *P. grandidentata.* Further away from the shore *Quercus rubra* and a few others were also found.

Hydrogen ion concentration was determined in the soil next to the roots of twelve representative species found in the different zones. The results are tabulated in Table I. The table shows readily that the H-ion concentration of the soil around the roots of these twelve plants has a very great range. When the small area under investigation is taken into account, it is remarkable that the difference is so great.

TABLE I

HYDROGEN ION CONCENTRATION OF THE SOIL AROUND THE ROOTS OF SOME PLANTS, NEAR HIGGINS LAKE, MICHIGAN

| Name of plant | pH | Remarks |
|---|---|---|
| Ledum groenlandicum | 3–4 | |
| Chamaedaphne calyculata | 3.5–4 | |
| Chimaphila umbellata | 3.5–5 | |
| Cypripedium acaule | 4–5 | |
| Epigaea repens | 4–6 | mostly pH 5 |
| Pyrola elliptica | 5–7.2 | mostly pH 5.5 |
| Campanula rotundifolia | 6–7.2 | one about pH 4.5 |
| Arctostaphylos Uva-ursi | 6–8 | mostly pH 7.0–7.5 |
| Rudbeckia hirta | 7.4–7.7 | |
| Gentiana procera | 7.5–8.0 | |
| Anemone cylindrica | 7.5–8.0 | |
| Mentha arvense var. canadensis | 7.7–8.5 | |

A word about the soil type around the roots of these plants may not be out of place. Ledum and Chamaedaphne both grew imbedded in sphagnum. Chimaphila had its roots surrounded by humus or sand; the lower part of the roots were always in sand. Cypripedium and Epigaea grew in humus, but the writer has found Cypripedium growing in sand near Woods Hole,

Massachusetts. Pyrola together with a few plants of Epigaea grew under two white pines, where the fallen needles had formed an island of humus surrounded by sand. This was the only place in which Pyrola grew in this area. There is no noticeable amount of clay near this part of Higgins Lake.

As a rule humus and high acidity go together and it is next to impossible to determine from field-studies whether the plant grows in a certain situation because of the presence of the humus or the acidity. Chimaphila growing in both sand and humus with practically constant H-ion concentration seems to point to the conclusion that it is the acidity which determines whether the plant will or will not grow in a certain situation. Kappen (8) has shown that high acidity is found in connection with humus by which it is produced. Sandy soil has also a high H-ion concentration in many situations, in fact many ecologists use the terms sandy soil and acid soil as synonyms.

In the preceding pages the writer has pointed out the differences in H-ion concentration which apparently influence the plant distribution. Many claim that aluminum influences plant growth to a great extent, while other investigators seem to find that it is of no special importance. In this area under investigation the presence or absence of aluminum has not been investigated. As the soil is either sand or humus-sand, however, without any noticeable amount of clay, it is pretty safe to assume that the aluminum is not a factor in the plant distribution in this locality.

Olsen found that plants which normally grow in acid soils will grow best in an acid liquid nutrient solution, showing that the H-ion concentration is the influencing factor and not the humus. The moisture does not seem to be an essential factor either. The writer has found *Cypripedium acaule* growing in sandy soil near Woods Hole, Massachusetts, in humus with underlying sand at Higgins Lake and in wet bogs at Ann Arbor, Michigan. The only thing these three situations had in common was the high H-ion concentration, and not the humus or moisture.

From these data it seems that, after all, the H-ion concentra-

tion is an important factor in the distribution of plants in this small area on the south shore of Higgins Lake. It is an especially good illustration because there is such an extreme change in acidity in a very small area, accompanied by an equally striking difference in the plant growth. In many instances plants of extreme acid habitats like Ledum and Chamaedaphne are found only some twenty feet away from plants like Rudbeckia and Prunella of neutral or slightly alkaline habitats.

There has been some discussion whether the hydrogen ions act directly or indirectly on the plant. It has been claimed that certain plants will not grow in a soil high in hydrogen ions, because nitrogen-fixing bacteria do not grow there, and the soil is thus left rich in ammonia but poor in nitrates. Olsen in his paper already referred to has shown quite conclusively that the plants are influenced directly by the hydrogen ions of the soil. If Olsen's work is taken as conclusively proving that the hydrogen ions act directly on the plant, the next question is, What is their effect upon the living plant? Several suggestions may be offered. The effect on the permeability of the cell may be such as to prevent most plants from developing in acid soil. In 1914 Osterhout (10, 11) showed that when the H-ion concentration of sea water is changed either by the addition of NaOH or HCl the permeability of the cells of Laminaria, as measured by electrical conductance, was increased, and after several hours in such solutions the cells were permanently injured.

Arrhenius (3), growing wheat and radish in nutrient solutions of different H-ion concentrations, found that less mineral material was absorbed from solutions of optimum H-ion concentration for growth than from solutions less favorable to growth. It has also been found by Waynick (13) that plants growing in solutions unfavorable to growth absorb more of certain elements than from more favorable solutions. Thus barley absorbs much more magnesium and calcium from solutions unfavorable to growth than from those better suited to barley requirements. Irwin (7) has found that when Nitella is changed to solutions of an H-ion concentration lower than that in which it normally grows, the

rate of absorption of the dye brilliant cresyl blue is greatly increased.

From the foregoing citations it is obvious that H-ion concentrations which are not favorable to growth of the plant or which are not normal to it increase the permeability of the cell. This action increases the ionic concentration of the cell beyond what the cell can make use of. It is well known that protein is coagulated by the ions of many salts, and an excess of ions in the cell may produce a tendency toward coagulation of the protoplasm. From work on antagonism comes the suggestion that an increase in permeability may destroy the balance of the cell sap, and thus bring about injury.

Miss Addoms (1) studied the effect of H-ion concentration on roots of wheat and she found that short, stubby and branched root-systems were associated with high H-ion concentrations, which were not favorable to the growth of the plant. Examining the root hairs of roots grown in various concentrations of hydrogen ions she found that the higher concentrations, i.e. those unfavorable to growth, produced coagulation of the protoplasm.

Pearsall and Ewing (12) have suggested that growth, i.e. synthesis of protoplasm, takes place most rapidly at or near the iso-electric point of the principal protein constituent of the protoplasm, because at this point the protoplasm would be least hydrated and the condensation of protein from amino acids most rapid. The protein leucosin from the actively growing tissue in wheat, these authors state, has its iso-electric point at pH 4.5. In the paper already referred to Arrhenius found that wheat grew best at pH 5.0. Pearsall and Ewing give the iso-electric point of globulin and albumin from yeast as pH 4.6, and they quote Mr. Mason of Leeds as stating that brewers yeast grows best at H-ion concentration of pH 4.5–5.0.

Any one of the three conditions suggested may effectively prevent plants from growing in a situation too acid or too alkaline. Thus when a plant which normally grows in a neutral soil is planted in a soil having a high H-ion concentration, the permeability of the cells may be so changed as to disturb the ionic balance in the cells, or the hydrogen ions themselves may bring

about a coagulation of the protoplasm as found by Miss Addoms in root hairs. Or if the reaction of the soil solution is far from the iso-electric point (on either side) of the principal protein of the protoplasm, growth (protein synthesis) may stop, as Pearsall and Ewing suggest. The reason we find some plants growing and thriving in very acid soil might be that they have developed a protoplasm which is not injured by a high concentration of hydrogen ions, but which is injured when the plants are grown in solutions or soils of low H-ion concentration, and such plants will no more live under such conditions than will a plant of neutral soil grow in an acid situation. There are more plants growing in soils having an acid reaction than in soils having an alkaline reaction, though most plants prefer a neutral or slightly acid soil. This may or may not be due to the fact that the protoplasm and cell sap of most plants are acid.

SUMMARY

1. From a study of the H-ion concentration of the soil near plant roots the writer believes that he has added further evidence for the belief that plant distribution to a great extent depends upon the active acidity concentration of the soil.

2. Several ways in which hydrogen ions may affect plant growth have been suggested.

University of Michigan

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# NOTES ON INDIAN RUDERALS

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DURING six years of botanical observations in India the writer devoted some attention to ruderals, because it was only in this group that old botanical acquaintances were recognized and because of the light that such studies would throw upon the interesting problem of plant dispersal. The trees and shrubs of the Indian plains belong entirely to different genera and for the most part to different families from our own. The trees and shrubs of the Himalayas represent some of the genera of our region, but the species are invariably different. The only plants which India possesses in common with us are the ruderals and weeds.

*A Weed Manual of Gwalior State* prepared by the writer in India describes one hundred and seventy-three weed species — a group fairly representative of the weedy vegetation of the Indian plains. Thirty of these are found in the area of Gray's *Manual.* Eleven of them are more or less cosmopolitan forms probably native to both India and the American area considered. They are:

1. *Eragrostis pilosa*
2. *Cyperus rotundus*
3. *Portulaca oleracea*
4. *Ranunculus sceleratus*
5. *Potentilla supina*
6. *Sida spinosa*
7. *Oxalis corniculata*
8. *Lippia nodiflora*
9. *Veronica anagallis*
10. *Solanum nigrum*
11. *Eclipta erecta*

Numbers 2, 8 and 11 are found only toward the southern part of the Gray's *Manual* range, and hence do not occur in Michigan.

Thirteen of the thirty species are indigenous to the Eurasian region and are in the United States by introduction. There are five grasses which prove quite as troublesome in the Indian region as in our own:

1. *Setaria glauca*
2. *Digitaria sanguinalis*
3. *Cynodon dactylon*
4. *Echinochloa crus-galli*
5. *Eragrostis minor*

Also the following dicotyledons:

6. *Chenopodium album*
7. *Chenopodium murale*
8. *Celosia argentea*
9. *Saponaria vaccaria*
10. *Spurgula arvensis*
11. *Convolvulus arvensis*
12. *Sonchus arvensis*
13. *Chicorium intybus*

*Argemone mexicana* (Mexican poppy), *Cassia obtusifolia*, and probably *Amaranthus spinosus* and *Amaranthus viridis* have been introduced into India from tropical America, whence also they have entered the Gray's *Manual* area. The latter two may belong to the cosmopolitan group, for their point of origin is uncertain. If we assume that they are American, these four, with five other tropical American plants not found in the northern United States, give nine American plants abundant enough on the plains of India to be regarded as weeds. This approximates the number of trouble-makers which have come in the other direction. Two grasses common to both areas, *Eleusine indica* and *Eleusine egyptica*, are indigenous to the Old World tropics.

Of the one hundred and seventy-three weeds described in the Gwalior manual, thirty-five are tropical cosmopolitan, four (*Setaria intermedia*, *Ranunculus sceleratus*, *Oxalis corniculata* and *Sonchus arvensis*) are temperate cosmopolitan, thirty-one are distributed through the old world tropics, nine belong to tropical America, thirteen are European, forty-three are Arabo-African, nineteen are Chinese and twenty-one are Indian endemics. The endemic flora of India is relatively small, most of the plants of that country having been adopted from neighboring lands.

It is of interest to note how American species are making their way about the world. Some are escapes from cultivation. Such tropical American fruits as guava, papaya and custard apple are widespread in cultivation in India, and are often found growing spontaneously. At one place seen by the writer the custard apple, *Anona squamosa*, was growing in such numbers

on a rocky hill about the ruins of an ancient fort that it gave the impression of being a native tree. The prickly pear cactus (various species of Opuntia) is said to have been introduced long ago in connection with a project to grow the cochineal insect. The insect did not thrive in India but Opuntia did, and now it is abundant over the drier parts of the country, planted for hedges or growing spontaneously.

An impressive chapter in the story of plant dispersal is that of American Compositae in India. Perhaps the most striking example is *Tridax procumbens*, which is found in almost every fence-row in tropical India. It has a wind-borne fruit with conspicuous pappus, and is almost as ubiquitous there as is the dandelion in our region. The Upper Gangetic Plain has no less than thirteen Compositae which are presumably American in origin. Five of these are dispersed by adhesive fruits: *Elephantopus scaber*, *Ageratum conzyoides*, *Xanthium strumarium*, *Bidens pilosa* and *Adenostemma viscosum*. Three are provided with hairy pappus and hence are wind-borne: *Erigeron canadensis*, *Gnaphalium purpureum* and *Tridax procumbens*. The others seem to have no special device for dispersal: *Siegesbeckia orientalis*, *Spilanthes acmella*, *Galinsoga parviflora*, *Lagascea mollis* and *Flaveria contrayerba*. The two named last have been in the range for so short a time that they are omitted from Duthie's *Flora of the Gangetic Plain*. The latter is omitted even from Hooker's *Flora of British India*.

During the summer of 1920 the writer took notes on ruderals while at the hill station of Landaur in the Western Himalayas and during a trip from this station to Gangotri, the reputed source of the Ganges, about 125 miles up this river from the point where it emerges into the plains. Ruderals are found in the cultivated fields, in waste places about villages, in camping-grounds and rather generally along roads and paths.

In a list of fifty-two species compiled from these notes there were nine endemics, twenty-four belonging to the Old World, twelve cosmopolitan and six from the New World.

The endemic list contains more of tropical forms belonging essentially to the Indian plains than of temperate forms.

The Old World list contains some very familiar weeds, among which are *Cannabis sativa* (hemp), an escape from cultivation, *Stellaria media, Nasturtium officinale, Verbascum thapsus, Capsella bursa-pastoris* and *Taraxacum officinale.* The shepherd's purse and dandelion extend up the valley from about 5,000 feet altitude to and beyond Gangotri at 10,000 feet.

The cosmopolitan list is as follows:

1. *Pteris aquilina*
2. *Poa pratensis*
3. *Plantago major*
4. *Arabis glabra*
5. *Barbarea vulgaris*
6. *Ranunculus sceleratus*
7. *Oxalis corniculata*
8. *Centunculus minimus*
9. *Veronica anagallis*
10. *Prunella vulgaris*
11. *Gnaphalium luteo-album*
12. *Bidens pilosa*
13. *Erigeron linifolius*

Pteris is much in evidence as a pioneer, and is not strictly confined to ruderal habits. *Oxalis corniculata* has the widest altitudinal range of any plant observed by the writer in India. It grows in shady places on the plains and extends to about 9,000 feet in the hills.

The New World species are:

1. *Amaranthus spinosus*
2. *Chenopodium anthelminticum*
3. *Oenothera rosea*
4. *Ipomoea hederacea*
5. *Tridax procumbens*
6. *Galinsoga parviflora*

Tridax is widespread over tropical India, but does not extend high in the Himalayas. *Galinsoga parviflora* is abundant in fields and along paths sixty miles back from the border of the Himalayas. It is a weak-looking unassuming plant from tropical America with no special device for the distribution of its fruits, yet it seems able to hold its own in a remarkable fashion. We find it rapidly getting a foothold in the streets of Chicago and other northern cities.

*Oenothera rosea,* a native of Peru, is now so widespread in the Himalayas that it appears to belong there. It was abundant about seventy-five miles back from the border of the range. Its introduction is fairly recent, for it was not reported by botanists who collected in the hills a century ago. The British botanist, H. N. Ridley, tells me that it is spreading in England, having been introduced as an ornamental plant and in some

cases rejected as not worth cultivating. This would seem to be a history similar to that of its more famous sister, *Oenothera lamarckiana*. The Peruvian plant has small seeds with no special distributional device. This, in fact, is true of the great majority of our fifty-two hill ruderals. It seems probable that they have been carried up and down the paths and from field to field largely by mechanical means, among which adhesion to mud on the feet of men and animals may be of some importance.

An interesting American introduction into India is *Lantana camara*, a prickly woody climber which has become a great nuisance in many sections as a forest weed. It may be seen in various places. At Kathgodam, a railway terminus at the foot of the hills, it was planted by one of the railway officials some years ago as an ornamental shrub. As the drupes are very attractive to birds, the shrub was spread until it is now an undergrowth in practically all the forest lands within a radius of a few miles of the station. The government has undertaken to find some natural enemy that will keep the weed in check. The investigation seems somewhat hopeful, but it has not yet given control of the pest which is annoying the forester in so many sections. So when we curse the English sparrow, the Russian thistle, the gypsy moth and other unwelcome introductions into our own country, we must remember that the score is not wholly against us.

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# INHERITANCE STUDIES OF WHITE-CAPPING IN YELLOW DENT MAIZE

CHANDRAKANT G. KULKARNI

## THE ORIGIN OF THE INVESTIGATION

THE late Professor F. A. Spragg had observed from time to time in the course of his researches and observations on corn that, when a yellow corn is pollinated by some white corns, the resulting $F_1$ kernels of these crosses were white-capped, thus indicating that white-capping was dominant to yellow-capping. He would have investigated the occurrence of the white cap, but because of other plant-breeding problems which he had in hand, the problem was allowed to rest.

Later, Mr. J. R. Duncan, research assistant at the Michigan Agricultural Experiment Station, brought to Professor Spragg for analysis a few ears of corn, some grains of which were white-capped. These kernels were the open pollinated crosses between Duncan and Silver King, Duncan being the female parent. The former is a yellow corn and the latter a white corn.

It was then suggested that the writer undertake a study of the white-capping factor or factors. Professor Spragg, who helped to plan the investigation and gave many suggestions, died before it was completed. This paper is a slight tribute to his memory.

## THE PROBLEM

As stated above, in the case of dent corns, white cap was observed to be dominant to the yellow cap, although no exact investigation had been carried on up to 1924, when the writer came to work under the direction of Professor Spragg as a graduate student. All the material pertaining to the white cap was given to the writer for further investigation. The problems to be investigated were: (1) Is white cap due to a Mendelian

factor or purely to the effect of the environmental conditions? (2) Is this factor an inhibitor, and if so, what tissues does it affect?

## PREVIOUS WORK ON THE YELLOW ENDOSPERM COLOR

An examination of a white-capped kernel reveals that the yellow pigment, so characteristic of a yellow corn, is entirely lacking in the cap region at the crown. This shows that white-capping is a condition of the endosperm. It was thought desirable, therefore, to review very briefly the previous work on the yellow endosperm color.

Two factors for the yellow endosperm color in maize have been described. The factor *Y* was first described by East (1910), although Correns (1901) had described it without giving it any symbol. Emerson (1911) also describes it. The factor *Yp* was first described by East (1910) and Emerson (1911). Correns (1901) describes a pale aleurone pigment in maize and this pale yellow was shown by Kvakan (1924) to be identical with brown aleurone (*Bn*). The factor *Y* gives a dark yellow color; when the modifying factors are present the factor *Y* also gives a deep orange color in the endosperm (Anderson, 1924). This orange color is due to the *Y* factor together with the modifying factors, because the kernels with the orange color show linkage with *Pl* factor, a factor for plant color in maize (Emerson, 1921; Anderson, 1924).

## MATERIAL USED IN THIS INVESTIGATION

As all the material used in this investigation came from different sources, it was thought desirable to tabulate it to make it more intelligible to the reader. These data are given in the following Table:

| Accession Number | Name | Description |
|---|---|---|
| 235 | Duncan | Yellow-cap yellow |
| 254 | Duncan | Yellow-cap yellow |
| 257 | Bailey Connecticut Yellow | Yellow-cap yellow |
| 265 | Clement's White Cap | White-cap yellow |
| 266 | Folk's White Cap | White-cap yellow |
| 267 | Silver King | White |
| 286 | Northwestern Dent | Red pericarp |

Accessions 235 and 254 are two inbred strains of yellow-cap yellow endosperm corn. Accession 257 is a cross between two inbred yellow-cap yellow endosperm strains. Accessions 265 and 266 are two different strains of white-cap yellow grown in the State of Michigan. Accession 267 is a commercial variety of the white corn. Accession 286 is also a commercial variety of corn. Accessions 235 and 254 were received from the Farm Crops Department of Michigan State College. Accession 257 was given to the writer by Professor Spragg, while Accessions 265, 266, 267 and 286 were received from Mr. J. R. Duncan.

## CLASSIFICATION AND SORTING

For the purpose of this investigation the material was sorted into four classes:

(1). Those grains whose caps were judged to be as white as any caps on the established white-capped variety. They were furnished by Mr. Duncan.

(2). Grains with white caps all somewhat darker than the lightest, some of them coming from the ears also showing segregation.

(3). This class consisted of grains whose caps were still darker than those in the second class. They came from the ears which were segregating for the pure yellow-capped grains.

(4). Ordinary yellow-capped grains.

For the purpose of classification there were assumed three dominant factors, $Wc_1$, $Wc_2$, $Wc_3$, and their allelomorphs, which are considered to be the absence of white-capping. $Wc_1$ is considered to be powerful enough to produce a fully white-capped yellow in the presence of $Y$, the factor for the yellow endosperm. $Wc_2$ is considered less powerful, and $Wc_3$ still less powerful, producing only light cap of very slight intensity.

*This hypothesis was not in the end substantiated, but was found useful in the analysis of the data. It worked out that there was only one factor for the white-capping; the other conditions were due to modifying factors.*

It was comparatively easy to sort the material in 1923 as the material received was well matured. But in 1924, because

of the shortness of the growing season, the material was not entirely mature when harvested and classification was difficult. If the material is even slightly immature, it is very hard to differentiate the various shades of white-capping. In 1925 the material was in an excellent condition for classification, as it had had a long growing season and hence was thoroughly mature.

### DESCRIPTION OF THE WHITE CAP

White-capped grain is easily distinguished from an unmodified yellow cap by the fact that the apex of the grain is white. Sections of the grain show that the soft starch portion of the endosperm which reaches the apex is in one case pure white and in the other slightly tinged with yellow. The yellow pigment that is so characteristic of the yellow grains with the yellow endosperm is entirely lacking in the cap region and as one examines a kernel with a white cap the characteristic yellow pigment is seen clearly just below the cap. The white-capping is due, therefore, to the elimination of the color by an inhibitor.

### INHERITANCE OF WHITE CAP ($Wc_1$)

#### *In Clement's White Cap*

In order to determine the inheritance of Clement's White Cap, it was crossed by Bailey Connecticut Yellow, the former being the female parent. These crosses were made in the year 1924. The $F_1$ seeds of these crosses gave only grains that were white-capped yellow. In Table I are summarized the results of these crosses.

When the $F_1$ white-capped seeds of these crosses were selfed in 1925, they gave a ratio of 3:1 of the white-capped grains to the yellow grains, thus establishing the fact that the white-capping in this case was due to a single dominant Mendelian factor. Table II shows the results of the analysis of these crosses. That the white-capping is due to a single factor in this strain can also be seen by the results of the backcrosses which are summarized in Table III.

### *In Folk's White Cap*

Folk's White Cap gives the same results as the Clement's White Cap. When it is crossed by a yellow, the $F_1$ kernels are all white-capped yellow (Table IV). When these $F_1$ kernels were selfed, they gave a ratio in $F_2$ of three white-capped grains to one yellow-capped grain (Table V), showing that the white-capping in this strain is also due to a single dominant Mendelian factor. The backcrosses substantiate the same conclusions (Table VI).

### *In Silver King*

In order to establish the existence of a white-capping factor definitely in Silver King, which might not be able to express itself in the absence of the yellow, Silver King was crossed by Bailey Connecticut Yellow. The $F_1$ seeds of these crosses were all white-capped yellow, thus proving the existence of a white-capping factor in Silver King. In Table VII are summarized the results of these crosses. These white-capped seeds of $F_1$ generation, when selfed the next year, gave a ratio of 3:1 for yellow to white grains (Table VIII).

The yellow grains on further classification for the white caps gave a ratio of 3:1 for the white caps to the yellows (Table IX). The backcross data substantiate the same conclusions (Table X). This indicates that the white cap obtained by crossing Silver King with Bailey Connecticut Yellow acts in the same way as did the Clement's White Cap and the Folk's White Cap, in that it is dominant in $F_1$ and segregates into a 3:1 ratio for the white-capped to the yellow-capped grains in $F_2$.

## DATA OBTAINED IN 1925 FOR THE DETERMINATION OF THE DOMINANCE OF THE WHITE CAP

The material was very hard to classify in 1924 because of the extreme immaturity. Since some kernels on each ear could not be classified (Tables I, IV, VII, last columns), it seemed desirable to make some crosses in 1925 of white caps with the yellow in order to determine definitely the dominance of the white cap.

With this aim in view, crosses were made between Duncan and Clement's White Cap, Duncan and Folk's White Cap, and Duncan and Silver King. The $F_1$ data of the cross Duncan and Clement's White Cap, as summarized in Table XI, those between Duncan and Folk's White Cap, as summarized in Table XII, and those between Duncan and Silver King, as summarized in Table XIII, indicate that the white-capping is dominant in all the cases, because all the grains from these crosses were only white-capped.

### INHERITANCE OF WHITE-CAPPING IN NORTHWESTERN DENT CORN

Northwestern Dent corn, with a colored pericarp except in the cap region, was selected for the white endosperm and crossed with Duncan. The resulting $F_1$ grains were all white-capped yellow (Table XIV), thus proving that in this case also the white-capping factor was dominant.

### INHERITANCE OF WHITE CAP ($Wc_2$)

The $F_2$ data and the backcrosses both in Clement's White Cap, Folk's White Cap and Silver King show $Wc_2$ to be dominant to the yellow-cap, and give a ratio of 3:1 for the white-capped to the yellow-capped grains in the $F_2$ generation, when selfed. The white caps in the $F_2$ generation show all the shades ($Wc_1$, $Wc_2$, $Wc_3$). This indicates that there must be modifying factors that cause the various shades of the white-capping. If there were no modifying factors, it would be expected that it would segregate in $F_2$ in a distinctly 3:1 ratio for $Wc_2$ to yellow on the basis of independent inheritance, which is not the case. In Tables XV, XVI, XVII and XVIIA are listed the results of these crosses.

The presence of the modifying factors can also be ascertained by studying the backcrosses $wcY \times (Wc_2Y \times wcY)$ from each of the foregoing strains. The results of these backcrosses are listed in Tables XVIII, XIX and XX.

If $Wc_2$ were an independent factor, it would segregate into a 1:1 ratio for $Wc_2$ to yellows in the backcrosses mentioned above,

which is not the case. The white caps obtained are not only $Wc_2$ but all the shades, $Wc_1$, $Wc_2$, $Wc_3$. This again substantiates the conclusions made above as to the modifying factors.

### INHERITANCE OF WHITE CAP ($Wc_3$)

$Wc_3$ from all the three strains mentioned above acts the same way as $Wc_2$ in all the crosses and the backcrosses, as can be seen from the data presented in Tables XXI, XXII, XXIII, XXIV and XXV. The data also indicate that $Wc_3$ is not inherited independently, as was assumed at the beginning, but is the outcome of the action of the modifying factors.

### SUMMARY

(1). A white-capping factor is described and is designated as *Wc*. It is inherited in a simple Mendelian way, the character being due to a single factor. It is dominant to the yellow-capping in the first generation and segregates in the second generation in a 3:1 ratio for the white-capped grains to the yellow-capped grains in Clement's White Cap, Folk's White Cap and Silver King.

(2). White-capping is due to an inhibitor which drives the color away from the crown of the kernel.

(3). Silver King, a white corn, carries a white-capping factor, but is unable to express it in the absence of the yellow endosperm.

(4). Various shades of white-capping are positively due to the presence of modifying factors.

In conclusion the author wishes to thank Professor E. E. Down and Mr. H. M. Brown, both of Michigan State College, for helpful suggestions and encouragement.

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## TABLE I

$F_1$ Progeny of the Cross Clement's White Cap (*WcY*), Acc. 265, × Bailey Connecticut Yellow (*wcY*,) Acc. 257

| No. | $Wc_1$ | $Wc_2$ | $Wc_3$ | Immature kernels not classifiable |
|---|---|---|---|---|
| 48901 | 188 | 51 | 62 | 13 |
| 48902 | 215 | 55 | 54 | 0 |
| 48903 | 311 | 195 | 196 | 0 |
| 48904 | 295 | 70 | 118 | 0 |
| 48905 | 343 | 164 | 147 | 0 |

There were about twenty ears of this cross, but only five of them were classified; the others were discarded because of extreme immaturity. No. 48905 was reserved for planting.

## TABLE II

$F_2$ Progeny of the Cross Clement's White Cap (*WcY*), Acc. 265, × Bailey Connecticut Yellow (*wcY*), Acc. 257

| No. | White cap yellow ($Wc_1Y$) | Yellow (Y) | Deviation from 3:1 ratio |
|---|---|---|---|
| 544802 | 372 | 129 | 3.75 ± 6.54 |
| 544804 | 289 | 94 | 1.75 ± 5.72 |
| 544806 | 338 | 120 | 5.50 ± 6.25 |
| 544806 A | 317 | 109 | 2.50 ± 6.03 |
| 544808 | 523 | 184 | 7.25 ± 7.77 |
| 544809 | 296 | 100 | 1.00 ± 5.81 |
| 544813 | 310 | 100 | 2.50 ± 5.91 |
| 544815 | 143 | 53 | 4.00 ± 4.09 |
| 544815 A | 430 | 141 | 1.75 ± 6.98 |
| 544818 | 363 | 120 | 0.75 ± 6.42 |
| 544819 | 312 | 106 | 1.50 ± 5.97 |
| 544819 A | 368 | 127 | 3.25 ± 6.50 |
| 544821 | 187 | 61 | 1.00 ± 4.60 |
| 544823 | 404 | 148 | 10.00 ± 6.86 |
| Total | 4652 | 1592 | |
| Calculated 3:1 | 4683 | 1561 | |
| Deviation | 31.00 ± 23.07 | | |

## TABLE III

Progenies of the Backcrosses Duncan (*wcY*), Acc. 235, × (Clement's White Cap (*WcY*), Acc. 265, × Bailey Connecticut Yellow (*wcY*), Acc. 257)

| No. | White cap yellow ($Wc_1Y$) | Yellow (Y) |
|---|---|---|
| 542917 × 544812 | 158 | 209 |
| 542902 × 544810 | 212 | 216 |
| 542917 × 544821 | 194 | 199 |
| 542920 × 544806 | 148 | 151 |
| Total | 712 | 775 |
| Calculated 1:1 | 743.5 | 743.5 |
| Deviation | 31.5 ± 13.01 | |

## TABLE IV

$F_1$ Progeny of the Cross Folk's White Cap (*WcY*), Acc. 266, × Bailey Connecticut Yellow (*wcY*), Acc. 257

| No. | $Wc_1$ | $Wc_2$ | $Wc_3$ | Immature kernels not classifiable |
|---|---|---|---|---|
| 49001 | 196 | 125 | 109 | 5 |
| 49002 | 503 | 70 | 77 | 16 |
| 49003 | 505 | 145 | 47 | 10 |

There were about thirty ears of this cross, of which only three were classified; the others were discarded because of extreme immaturity. No. 49002 was reserved for planting.

## TABLE V

$F_2$ Progeny of the Cross Folk's White Cap (*WcY*), Acc. 266, × Bailey Connecticut Yellow (*wcY*), Acc. 257

| No. | White cap yellow ($Wc_1Y$) | Yellow (Y) | Deviation from 3:1 ratio |
|---|---|---|---|
| 545101 | 354 | 123 | 3.75 ± 6.38 |
| 545101 A | 284 | 91 | 2.75 ± 5.66 |
| 545105 | 214 | 75 | 2.75 ± 4.97 |
| 545105 A | 327 | 112 | 2.25 ± 6.12 |
| 545106 | 373 | 123 | 1.00 ± 6.50 |
| 545109 | 261 | 96 | 6.75 ± 5.52 |
| 545110 | 361 | 128 | 5.75 ± 6.46 |
| 545113 | 277 | 89 | 2.50 ± 5.59 |
| Total | 2451 | 837 | |
| Calculated 3:1 | 2466 | 822 | |
| Deviation | 15.00 ± 16.73 | | |

## TABLE VI

PROGENIES OF THE BACKCROSSES DUNCAN (*wcY*), Acc. 235, × (FOLK'S WHITE CAP (*WcY*), Acc. 266, × BAILEY CONNECTICUT YELLOW (*WcY*), Acc. 257)

| No. | White cap yellow ($Wc_1Y$) | Yellow |
|---|---|---|
| 542909 × 545107 | 198 | 196 |
| 543941 × 545112 | 172 | 167 |
| 543943 × 545113 | 260 | 254 |
| 542943 × 545117 | 180 | 180 |
| Total | 810 | 797 |
| Calculated 1:1 | 803.5 | 803.5 |
| Deviation | $6.5 \pm 13.52$ | |

## TABLE VII

$F_1$ PROGENY OF THE CROSS SILVER KING (*wcy*), Acc. 267, × BAILEY CONNECTICUT YELLOW (*wcY*), Acc. 257

| No. | $Wc_1$ | $Wc_2$ | $Wc_3$ | Immature kernels not classifiable |
|---|---|---|---|---|
| 49101 | 108 | 65 | 199 | 143 |
| 49102 | 39 | 37 | 61 | 0 |
| 49103 | 79 | 38 | 125 | 141 |
| 49104 | 70 | 32 | 47 | 165 |
| 49105 | 128 | 56 | 91 | 236 |

There were about thirty-five ears of this cross, but only five were classified; the others were discarded because of extreme immaturity. No. 49101 was reserved for planting.

## TABLE VIII

$F_2$ Data of the Cross Silver King (*wcy*), Acc. 267, × Bailey Connecticut Yellow (*wcY*), Acc. 257

| No. | Yellow (Y) | White (y) | Deviation from 3:1 ratio |
|---|---|---|---|
| 545501 | 327 | 101 | 6.00 ± 6.04 |
| 545501 A | 502 | 165 | 1.75 ± 7.54 |
| 545502 | 394 | 134 | 2.00 ± 6.71 |
| 545503 | 204 | 62 | 4.50 ± 4.76 |
| 545504 | 387 | 146 | 12.75 ± 6.74 |
| 545509 | 197 | 64 | 1.25 ± 4.72 |
| 545511 | 377 | 114 | 8.75 ± 6.47 |
| 545513 | 497 | 174 | 6.25 ± 7.57 |
| 545314 | 263 | 72 | 11.75 ± 5.35 |
| Total | 3148 | 1032 | |
| Calculated3:1 | 3135 | 1045 | |
| Deviation | 13.00 ± 18.86 | | |

## TABLE IX

Further Classification of the Yellow Grains of Table VIII

| No. | White cap yellow ($Wc_1Y$) | Yellow (Y) | Deviation from 3:1 ratio |
|---|---|---|---|
| 545501 | 240 | 87 | 5.25 ± 5.28 |
| 545501 A | 375 | 127 | 1.50 ± 6.54 |
| 545502 | 291 | 103 | 4.50 ± 5.80 |
| 545503 | 152 | 52 | 1.00 ± 4.17 |
| 545504 | 292 | 95 | 1.75 ± 5.75 |
| 545509 | 149 | 48 | 1.25 ± 4.10 |
| 545511 | 282 | 95 | 0.75 ± 5.67 |
| 545513 | 373 | 124 | 0.25 ± 6.51 |
| 545514 | 198 | 65 | 0.75 ± 4.74 |
| Total | 2352 | 796 | |
| Calculated 3:1 | 2361 | 787 | |
| Deviation | 9.00 ± 16.38 | | |

## TABLE X

PROGENIES OF THE BACKCROSS DUNCAN (*wcY*), Acc. 254, × SILVER KING (*Wcy*), Acc. 267, × BAILEY CONNECTICUT YELLOW (*wcY*), Acc. 257

| No. | White cap yellow ($Wc_1Y$) | Yellow (Y) |
|---|---|---|
| 545914 × 545509 | 202 | 212 |
| 546032 × 545511 | 130 | 114 |
| 543806 × 545514 | 128 | 135 |
| Total | 460 | 461 |
| Calculated 1:1 | 460.5 | 460.5 |
| Deviation | 0.5 ± 8.86 | |

## TABLE XI

$F_1$ PROGENY OF THE CROSS DUNCAN (*wcY*), Acc. 235, × CLEMENT'S WHITE CAP (*WcY*), Acc. 265

| No. | White cap yellow (WcY) | Yellow (Y) |
|---|---|---|
| 542937 × 542312 | 335 | 0 |
| 542212 × 542317 | 486 | 0 |
| 542801 × 542318 | 453 | 0 |
| 542932 × 542402 | 387 | 0 |
| 542804 × 542405 | 332 | 0 |
| 542803 × 542406 | 499 | 5 |
| 542238 × 542416 | 385 | 0 |
| 542605 × 542505 | 432 | 0 |
| 542003 × 542505 | 323 | 0 |
| 542918 × 542507 | 404 | 0 |
| 542019 × 542513 | 323 | 0 |
| 542924 × 542602 | 267 | 0 |
| 542927 × 542606 | 368 | 0 |
| 542808 × 542612 | 264 | 0 |
| 542911 × 542702 | 328 | 0 |
| 542902 × 542703 | 314 | 0 |
| 542903 × 542704 | 297 | 0 |
| 542920 × 542710 | 237 | 0 |

## TABLE XII

$F_1$ Progeny of the Cross Duncan (*wcY*), Acc. 235, × Folk's White Cap (*WcY*), Acc. 266

| No. | White cap yellow (WcY) | Yellow (Y) |
|---|---|---|
| 542921 × 543002 | 295 | 0 |
| 542913 × 543004 | 225 | 0 |
| 542808 × 543108 | 357 | 0 |
| 542811 × 543111 | 389 | 10 |
| 542816 × 543112 | 402 | 0 |
| 542942 × 543302 | 439 | 0 |
| 543702 × 543308 | 296 | 0 |
| 542938 × 543512 | 308 | 0 |
| 542933 × 543515 | 244 | 0 |
| 542817 × 543516 | 156 | 0 |

## TABLE XIII

$F_1$ Progeny of the Cross Duncan (*wcY*), Acc. 235, × Silver King (*Wcy*), Acc. 267

| No. | White cap yellow (WcY) | Yellow (Y) |
|---|---|---|
| 542931 × 543406 | 376 | 0 |
| 542218 × 543408 | 482 | 0 |
| 542814 × 543409 | 256 | 0 |
| 542234 × 543415 | 247 | 0 |
| 543728 × 543601 | 308 | 0 |
| 543801 × 543604 | 92 | 0 |
| 542933 × 543606 | 356 | 0 |

## TABLE XIV

$F_1$ Progeny of the Cross Duncan (*wcY*), Acc. 235, × Northwestern Dent (*Wcy*), Acc. 286

| No. | White cap yellow (WcY) | Yellow (Y) |
|---|---|---|
| 542223 × 544501 | 426 | 0 |
| 546010 × 544503 | 368 | 0 |
| 544705 × 544507 | 289 | 0 |
| 542219 × 544508 | 536 | 0 |
| 546009 × 544511 | 395 | 0 |
| 542227 × 544513 | 145 | 0 |
| 542226 × 544514 | 375 | 4 |

## TABLE XV

$F_2$ Progeny of the Cross Clement's White Cap (*$Wc_2Y$*), Acc. 265, × Bailey Connecticut Yellow (*wcY*), Acc. 257. *$Wc_2$* Grains from $F_1$ Planted and Selfed

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow | Deviation from 3:1 ratio |
|---|---|---|---|---|---|---|
| 544901 | 86 | 306 | 133 | 525 | 178 | 2.25 ± 7.74 |
| 544902 | 79 | 292 | 124 | 495 | 160 | 3.75 ± 7.47 |
| 544904 | 73 | 285 | 129 | 487 | 170 | 5.75 ± 7.49 |
| 544906 | 56 | 149 | 95 | 300 | 97 | 2.25 ± 5.82 |
| 544908 | 64 | 267 | 93 | 424 | 141 | 0.25 ± 6.94 |
| Total | 358 | 1299 | 574 | 2231 | 746 | |
| Calculated 3:1 | | | | 2232.75 | 744.25 | |
| Deviation | | | | 1.75 ± 15.94 | | |

## TABLE XVI

$F_2$ Progeny of the Cross Folk's White Cap (*WcY*), Acc. 266, × Bailey Connecticut Yellow (*wcY*), Acc. 257. *Wc*$_2$ Grains from $F_1$ Planted and Selfed

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow | Deviation from 3:1 ratio |
|---|---|---|---|---|---|---|
| 545202 | 46 | 108 | 66 | 220 | 74 | 0.50 ± 5.01 |
| 545204 | 60 | 143 | 100 | 303 | 109 | 6.00 ± 5.93 |
| 545208 | 52 | 124 | 83 | 259 | 93 | 5.00 ± 5.48 |
| 545209 | 30 | 77 | 55 | 162 | 60 | 4.50 ± 4.35 |
| 545211 | 43 | 105 | 67 | 215 | 76 | 3.25 ± 4.98 |
| Total | 231 | 557 | 371 | 1159 | 412 | |
| Calculated 3:1 | | | | 1178.25 | 392.75 | |
| Deviation | 19.85 ± 11.58 | | | | | |

## TABLE XVII

$F_2$ Progeny of the Cross Silver King (*Wcy*), Acc. 267, × Bailey Connecticut Yellow (*wcY*), Acc. 257. *Wc*$_2$ Grains Planted and Self-Pollinated

| No. | Yellow (Y) | White (y) | Deviation from 3:1 ratio |
|---|---|---|---|
| 545605 | 384 | 128 | 0 ± 6.61 |
| 545606 | 389 | 116 | 10.25 ± 6.56 |
| 545608 | 345 | 99 | 12.00 ± 6.15 |
| 545610 | 386 | 122 | 5.00 ± 6.58 |
| Total | 1504 | 465 | |
| Calculated 3:1 | 1476.75 | 492.25 | |
| Deviation | 27.25 ± 12.96 | | |

## TABLE XVII A

FURTHER CLASSIFICATION OF THE YELLOW GRAINS OF TABLE XVII

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) | Deviation from 3:1 ratio |
|---|---|---|---|---|---|---|
| 545605 | 41 | 185 | 63 | 289 | 95 | 1.00 ± 5.72 |
| 545606 | 45 | 179 | 66 | 290 | 99 | 1.75 ± 5.76 |
| 545608 | 36 | 170 | 53 | 259 | 86 | 0.25 ± 5.42 |
| 545610 | 49 | 167 | 74 | 290 | 96 | 0.50 ± 5.74 |
| Total | 171 | 701 | 256 | 1128 | 376 | |
| Calculated 3:1 | | | | 1128 | 376 | |
| Deviation | | | | 0 ± 11.33 | | |

## TABLE XVIII

PROGENIES OF THE BACKCROSS DUNCAN (*wcY*), Acc. 254, × (CLEMENT'S WHITE CAP (*Wc*$_2$Y), Acc. 265, × BAILEY CONNECTICUT YELLOW (*wcY*), Acc. 257). *Wc*$_2$ GRAINS PLANTED

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) |
|---|---|---|---|---|---|
| 542914 × 544903 | 29 | 118 | 82 | 229 | 224 |
| 545914 × 544909 | 20 | 94 | 45 | 159 | 172 |
| 542906 × 544910 | 24 | 113 | 61 | 198 | 204 |
| Total | 73 | 325 | 188 | 586 | 600 |
| Calculated 1:1 | | | | 593 | 593 |
| Deviation | | | | 7.00 ± 11.60 | |

## TABLE XIX

Progenies of the Backcross Duncan (*wcY*), Acc. 254, × (Folk's White Cap (*WcY*), Acc. 266 × Bailey Connecticut Yellow (*wcY*), Acc. 257). $Wc_2$ Grains Planted

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow |
|---|---|---|---|---|---|
| 545903 × 545202 | 22 | 63 | 39 | 124 | 110 |
| 546028 × 545203 | 34 | 89 | 54 | 177 | 166 |
| 544711 × 545211 | 44 | 107 | 65 | 216 | 249 |
| To al | 100 | 259 | 158 | 517 | 525 |
| Calculated 1:1 | | | | 521 | 521 |
| Deviation | | | | | 4.00 ± 10.88 |

## TABLE XX

Progenies of the Backcross Duncan (*wcY*), Acc. 254, × (Silver King (*Wcy*), Acc. 267, × Bailey Connecticut Yellow (*wcY*), Acc. 257). $Wc_2$ Grains Planted

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) |
|---|---|---|---|---|---|
| 544721 × 545602 | 9 | 47 | 16 | 72 | 73 |
| 546014 × 545606 | 15 | 77 | 30 | 122 | 134 |
| Total | 24 | 124 | 46 | 194 | 207 |
| Calculated 1:1 | | | | 200.5 | 200.5 |
| Deviation | | | | | 6.5 ± 6.75 |

## TABLE XXI

$F_2$ Progeny of the Cross Clement's White Cap ($Wc_3Y$), Acc. 265, × Bailey Connecticut Yellow ($wcY$), Acc. 257. $Wc_3$ Grains from $F_1$ Planted and Selfed

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) | Deviation from 3:1 ratio |
|---|---|---|---|---|---|---|
| 545001 | 15 | 23 | 48 | 86 | 29 | 0.25 ± 3.13 |
| 545004 | 44 | 105 | 200 | 349 | 118 | 1.25 ± 6.31 |
| 545006 | 31 | 86 | 125 | 242 | 75 | 4.25 ± 5.20 |
| 545011 | 35 | 84 | 155 | 274 | 91 | 0.25 ± 5.58 |
| 545012 | 54 | 129 | 248 | 431 | 141 | 2.00 ± 6.99 |
| 545014 | 34 | 88 | 180 | 302 | 98 | 2.00 ± 5.84 |
| Total | 213 | 515 | 956 | 1684 | 552 | |
| Calculated 3:1 | | | | 1677 | 559 | |
| Deviation | 7.00 ± 13.83 | | | | | |

## TABLE XXII

$F_2$ Progeny of the Cross Folk's White Cap ($Wc_3Y$), Acc. 266, × Bailey Connecticut Yellow ($wcY$), Acc. 257. $Wc_3$ Grains from $F_1$ Planted and Selfed

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) | Deviation from 3:1 ratio |
|---|---|---|---|---|---|---|
| 545301 | 59 | 46 | 149 | 254 | 83 | 1.25 ± 5.36 |
| 545302 | 89 | 65 | 232 | 386 | 127 | 1.25 ± 6.62 |
| 545305 | 101 | 79 | 260 | 440 | 160 | 10.00 ± 7.15 |
| 545307 | 72 | 55 | 178 | 305 | 97 | 3.50 ± 5.86 |
| 545308 | 97 | 74 | 238 | 409 | 139 | 2.00 ± 6.84 |
| 545310 | 107 | 81 | 260 | 448 | 145 | 3.25 ± 7.11 |
| Total | 525 | 400 | 1317 | 2242 | 751 | |
| Calculated 3:1 | | | | 2244.75 | 748.25 | |
| Deviation | 2.75 ± 15.97 | | | | | |

## TABLE XXIII

PROGENIES OF THE BACKCROSS DUNCAN (*wcY*), Acc. 254, × (CLEMENT'S WHITE CAP (*Wc₃Y*), Acc. 265, × BAILEY CONNECTICUT YELLOW (*wcY*), Acc. 257). *Wc₃* GRAINS PLANTED

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) |
|---|---|---|---|---|---|
| 543807 × 545004 | 19 | 42 | 77 | 138 | 141 |
| 546009 × 545010 | 15 | 36 | 67 | 118 | 119 |
| 542916 × 545011 | 29 | 69 | 128 | 226 | 230 |
| Total | 63 | 147 | 272 | 482 | 490 |
| Calculated 1:1 | | | | 486 | 486 |
| Deviation | | | | 4.00 ± 10.51 | |

## TABLE XXIV

PROGENIES OF THE BACKCROSS DUNCAN (*wcY*), Acc. 254, × (FOLK'S WHITE CAP (*Wc₃Y*), Acc. 266, × BAILEY CONNECTICUT YELLOW (*wcY*), Acc. 257). *Wc₃* GRAINS PLANTED

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) |
|---|---|---|---|---|---|
| 544707 × 545304 | 29 | 22 | 67 | 118 | 128 |
| 544604 × 545308 | 50 | 38 | 118 | 206 | 208 |
| Total | 79 | 60 | 185 | 324 | 336 |
| Calculated 1:1 | | | | 330 | 330 |
| Deviation | | | | 6.00 ± 8.66 | |

## TABLE XXV

PROGENIES OF THE BACKCROSS DUNCAN (*wcY*), Acc. 254, × (SILVER KING (*Wcy*), Acc. 267, × BAILEY CONNECTICUT YELLOW (*wcY*), Acc. 257). $Wc_3$ GRAINS PLANTED

| No. | $Wc_1Y$ | $Wc_2Y$ | $Wc_3Y$ | Total white cap yellow | Yellow (Y) |
|---|---|---|---|---|---|
| 546024 × 545704 | 21 | 30 | 78 | 129 | 130 |
| 545905 × 545710 | 17 | 22 | 71 | 110 | 115 |
| 545904 × 545715 | 23 | 36 | 69 | 128 | 133 |
| Total | 61 | 88 | 218 | 367 | 378 |
| Calculated 1:1 | | | | 372.5 | 372.5 |
| Deviation | | | | $5.5 \pm 9.20$ | |

# CELL DISJUNCTION IN SPIROGYRA

FRANCIS E. LLOYD

IN SPIROGYRA, as also in its near congener Mougeotia, there are two types of cell disjunction, one purely mechanical, so far as it has been comprehended, the other involving hydrolysis of the cell-wall. The former occurs in the smaller, thin-walled species of Spirogyra with replicate dissepiments (Text Fig. 4 A–C) and probably to some extent in non-replicate species, and, to a notable extent in Mougeotia; the latter in some, probably all, the thick-walled species of Spirogyra (Pl. XIX, Figs. 1–10.) There has been occasion to reëxamine the matter with the gleaning of evidence necessitating some amendment of the accounts of earlier investigators. Motion photomicrography has been used to record behavior in *S. Weberi.*

According to Benecke (1898), there are two types of occurrence in Mougeotia characterizing severally the small and large species. In the large species the transverse wall is somewhat lenticular, as stated by various authors. After plasmolysis, the two moieties of the transverse wall separate to form two hemispherical shells between which there now occurs a pretty large space with the meager remains of intercellular substance inclosed. Benecke was unable to demonstrate an intercellular substance, though Klebs had mentioned a gelatinous plug as filling the space, but having nothing to do with normal fragmentation. The second type, embracing the small species, differs in having a gelatinous mass between the lamellae, in the plasmolysed condition becoming, together with the two apposed walls, nearly spherical.

I have reëxamined two representative species, one with a diameter of 20 microns, the other about 5 microns. In both of these I was able to demonstrate most convincingly by using ruthenium red that, in the plasmolysed condition, the space be-

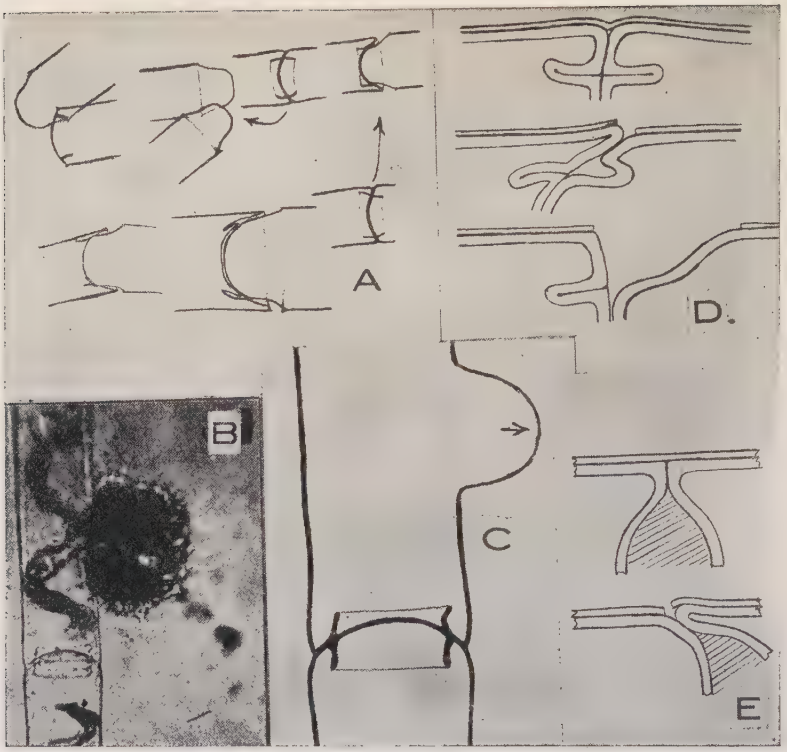


FIGURE 4

*A.* Various cell junctures just previous to, and after, abjection. Those connected by arrows traced from motion photomicrographs.

*B.* Enlargement from motion photomicrograph of Vampyrella attacking a cell of *Spirogyra Weberi*, taken within less than one second of abjection.

*C.* Sketch of B (traced on projection), the curvatures slightly exaggerated. The arrow indicates direction of bursting of the hydrolysed cell-wall, easily traceable in a properly printed diapositive.

*D.* Schemes to show the mechanism of rupture in *S. Weberi.*

*E.* Schemes to show mechanism of rupture in Mougeotia. The hatching indicates intercellular gelatinous material.

tween the apposed transverse walls is occupied fully by a gelatinous substance (Figs. 11–14). This I have been able in the case of the small species to set free after abjection induced by gentle plasmolysis with glycerine after previous staining with ruthenium red, photographing it by means of green light (Fig. 12). Commonly the material is lost to sight on abjection. By previous staining, however, and by making use of a coagulating effect of the stain, the matter is made clear. Three cases were chosen to illustrate the variety of result: Case 1. — The gelatinous mass remained adherent to the end of a cell after abjection (Fig. 12); Case 2. — The two cells adhered by means of the gelatinous mass (Fig. 13); Case 3. — The two cells had been displaced after abjection and the gelatinous mass, remaining adherent to both now free cell-ends, was drawn out into a slimy thread (Fig. 14). In the large species, which I had in preserved condition only, the mass was stained and showed to fill the space in question (Fig. 11). We may conclude that Klebs was right. That the presence of this material has nothing to do with abjection, however, is questionable. We must note that before plasmolysis the protoplasts, by their turgor, can and do compress the mass, just as the cell-wall in certain large species of Spirogyra (*S. nitida, aff.*) and in some other algae is compressed, and, on plasmolysis, is released and swells at once to several times its normal thickness (Fig. 2). The presence of this lenticular body causes greater differences in curvature when, by plasmolysis, the cytoplasm is withdrawn, than would occur if it were absent, and hence a greater shearing strain on the common wall at the junction of the cells. Though the same physical principle is involved, that of the lever, it is a more effective one when the gelatinous mass is present between the walls than if absent (Text Fig. 4 E). This difference is not negligible, as must appear on comparing the diagrams provided by Benecke with those presented herewith.

The same principle is used also in the abjection of cells by Spirogyra, whether the species possesses replicate end-walls or not, but it is a matter of common knowledge that the former are much more prone to abjection and in them it takes place promptly and with ease, if, for any reason, the turgor

of a cell is sufficiently lowered. This can happen however a cell may be damaged or destroyed, a notable example being the behavior when a cell is attacked by Vampyrella (Lloyd, 1927). Studies made by means of photomicrography made it possible to analyze the steps leading to abjection. Inasmuch as the act of separation takes place within a small fraction of a second, it is impossible with the eye alone to see just what happens. The present account, which embraces an amendment to the original narrative by Cohn (1850, through Oltmanns), is based on the motion picture record.

The species studied is *Spirogyra Weberi*, with replicate end-walls. When attacked by Vampyrella, in order to get at the contents of the cell, the animal digests an oval area of the longitudinal wall which, during the earlier phase of hydrolysis, bulges outward into the animal until it bursts (Text Fig. 4 B, C). At the moment of bursting, or just before, abjection of the attacked cell takes place. Previous to this, however, the increase in volume of the cell in the measure of the bulging of the hydrolysed area results in lowering of the pressure on the end-walls, which, in consequence, bulge inward until they become distinctly concave, but *only watch-glass shaped* (Text Fig. 4 A, C). Before abjection there is *never any unfolding of the replications.* According to Cohn, the replication in the abjected cell is more or less straightened out, and the cell-wall proper is peeled away from the common wall for a short distance before tearing occurs. That this is not the case is shown by the fact that abjection often takes place, so as to leave the replications in the discarded cell in their original condition, with the common wall tightly in place as before; or, on the other hand, the replications may be straightened out in like manner, namely outwardly, in both the healthy and the discarded cells, according to whether abjection took place at the same moment with the bursting of the attacked cell (because of the act of digestion by Vampyrella, as described above), or just before. In the former case, the complete loss of turgor releases all the energy available for pushing out the end-wall, so that the replication is left unaffected. The photographic record (Text Fig. 4 B) shows that, at the

moment of abjection, the longitudinal walls in the vicinity of the end-walls display curvatures due to the altered strains which make clear the manner in which the shearing strain, resulting in tearing the longitudinal wall, is produced. The diagram herewith (Text Fig. 4 C) was made by tracing the projected photograph (Text Fig. 4 B) exaggerating the curvatures slightly. The additional diagrams (Text Fig. 4 D) serve to present the view here advanced that the tearing takes place unaccompanied by the invagination, or any unfolding of the replication of the discarded cell. The tear is produced, according to this view, by the sharp shearing strain resulting from the compression of the fold between the longitudinal and transverse wall by the evaginating end of the turgid cell, opposed to strain in the opposite sense near by in the wall of the latter.

Such a shearing strain is necessary to the tearing of the longitudinal wall, since the pull on the longitudinal wall exerted by the combined pressures of two cells is insufficient; and since the condition for tearing is established after a reduction of the total pressure by a loss of turgor by one of the cells, the strain must be applied in a more effective way. It is, however, also necessary to assume that the intercellular substance (middle lamella) is loose (pectose changed to pectin, Tiffany, 1923) or has disappeared. In material kept in glycerin the relaxed transverse walls are nearly always loosened from one another in *S. Weberi*, while in *S. longata* they are rarely so, and I have been unable either in this material of *S. Weberi*, or in living material, to see any evidence of the middle lamella. The condition here seems, therefore, to parallel that in Mougeotia in that abjection is made possible by the mutual freedom of the apposed transverse walls.

Far different is the method of cell disjunction in *S. nitida*, a thick-walled species.[1] The process involves local hydrolysis of the cell-wall in such a manner as to set free pieces of the longitudinal wall with the attached portion of the end-walls, the so-

[1] Our material answers best to the description of *S. nitida* (according to a key elaborated by Professor Transeau kindly furnished to me by him), but has cells 0.6 to 0.8 mm. long.

called H-pieces. The method was first described by Strasburger (1875) for *S. orthospira*, but seems not to be very widely known. It is of interest in that the process is very similar in almost every respect to the behavior of the individual cells during abscission in the higher plants.

Strasburger's description was based on a species also having thick walls, and it may be remarked that a purely mechanical method of cell disjunction is not possible except in thin-walled species. Evidence of abscission is to be seen in a circular rift in the wall a short distance from the end of the cell. In this way a hoop-shaped piece (the H-piece) is separated. By means of the turgor pressure the rounded end of the cell is pushed away from this piece, leaving the other cell with the separated H-piece as a cap. Only one cell is separated, though later on the other throws off the cap. The position of the line of disruption is determined by the extent of cuticularization of the three-cornered piece (which I take to mean the H-piece). Abscission takes place under unfavorable conditions, and Strasburger also induced it by cutting filaments, from which, in the course of twenty-four hours, the injured cells were thrown off.

I have repeated the experiment of cutting the filaments with like result (Figs. 2, 3). Abscission also took place spontaneously in a small shallow dish in which there was decay of various forms and in which the plant was infested by fungi (Figs. 5–7). It was not apparent, however, that abscission was always the result of fungus attack, though this invariably led to it. This material has afforded information in regard to certain details not previously touched upon.

With regard to the position of the rift, Strasburger makes the point that it occurs at the limits of cuticularization of the "Drieck." According to my observations, the rift falls at the limit of the H-piece, but these statements may mean the same. The H-piece has, however, not been regarded as a feature of the Spirogyra cell save in the case of *S. colligata* described by Hodgetts (1920), until recently when Steinecke (1926) found it in a species identified as close to if not identical with *S. adnata*. Steinecke's rough sketches do not permit one to visual-

ize very accurately what he saw; but it must be apparent that the growth of the wall of Spirogyra is such that at the oldest region, namely the zone surrounding the oldest end-walls, there must be a different structure quantitatively than at the younger similar regions. Qualitative differences also inhere (Van Wisselingh, 1924, p. 222), as I have also observed. This fact is brought out quite clearly in the species here under discussion, in which, after treatment with sulphuric acid or zinc chloride, the H-pieces stand out quite distinctly. At cell junctures of the same origin in time they have the same dimensions; younger cell junctures have less massive H-pieces. It is approximately at the limit of this H-piece that abscission occurs, but only in a living cell (Fig. 8).

The first visible indication that this event is in progress is seen in the gradual disappearance of the so-called mucilage layer, which becomes more and more translucent till it finally fades from the vision. This change involves both the mucilage proper and the "Rosaschicht" of Strasburger, but does not involve the rods [2] (Figs. 3–7), since these are set free intact. When treated with sulphuric acid (1 per cent solution), the mucilage at once disappears in solution, leaving the rods attached to the basal membrane ("Rosaschicht"?). In successful preparations, however, it can be seen that the basal membrane has disappeared during the earliest visible phase of abscission, though not the rods, which are at least much more resistant than the mucilage. I have repeatedly seen the rods lying free and unaffected, showing this resistance and proving that they are set free from the basal membrane, which is not the case when sulphuric acid is used (Figs. 9–10).

The hydrolytic action next passes into the outer cellulose layer of the common wall, hence into the cellulose wall proper of the cell as far as the innermost membrane investing the protoplast, whereupon this membrane becomes distended by the turgor of the cell. From this point the action spreads around the end

[2] The rods seen in the mucilage layer were accurately described by Strasburger and had been seen by others before him (Braun and Naegeli). They appear to have a high degree of development in *S. colligata* (Hodgetts).

of the cell in the cellulose wall proper to the cell, thus setting up a loose watery layer of hydrocellulose with little tenacity (Fig. 6). This sets free the cellulose wall from the middle lamella, which in this species is tightly affixed to the secondary membranes, as can be seen when cells which are in a very early condition of abscission are spread apart (Fig. 7). Commonly, however, some outer portion of the secondary wall adheres to the middle lamella, though naturally this depends on how far the process of hydrolysis has been allowed to proceed before actual separation is achieved. This takes place in nature by the rounding of the end of the cell, whose bulging then causes it to slip from the H-piece (Fig. 5). The more massive gelatinous mass arising from the hydrated wall may now be seen (Fig. 6, the upper cell-end).

Whether the alteration in the physical character of the cellulose layer which proceeds around the end of the cell setting it free from the H-piece is due to specific activity, or is merely the reaction of the cellulose to the water which has access to it when the outer layer is demolished, is a question which cannot be answered. We know, however, that when a cell is plasmolysed, the wall swells greatly; this happens also when we cut cells across (Fig. 2), as was done when repeating the experiment performed by Strasburger. It is not long thereafter that one can see clearly the laminated structure of the wall, made evident by its extensive hydration (Fig. 3). The mere freedom from compression on the tearing of the outer membrane, therefore, would permit such swelling. The simpler explanation, that the setting free of the cell is due merely to the swelling made possible by release of compressing structures, will serve till further evidence is forthcoming.

The cell-end thus set free is clothed by an exceedingly thin cellulose wall, devoid of a mucilage layer (Figs. 5–7). In a short time, however, this arises *de novo* (Fig. 9). It can then be followed into the angle formed by the loosened membrane, the edge of which is expanded and forms a loose fringe banding the cell and marking the position of the original rift (Strasburger). It does not seem to be continuous, however, with any layer

existing previous to abscission, but arises either by alteration of the external layer of the newly exposed cellulose wall, or by excretion. The latter view may be traced to Klebs (*vide* Oltmanns, 1904) and the evidence supports his contention. But whether the excretion is related to the rods, as Klebs also argued, is not so evident. Their numbers in *S. nitida* are frequently very few, or again large. They resist the action of zinc chloride in concentrated solution, as also chlorzinc iodine, and in this condition simulate bacteria, as Strasburger remarks in his *Prakticum*. They are distinctly more resistant to these reagents than the mucilage layer itself. While not present in the newly formed mucilage layer, they shortly appear at first in one's and two's, then more abundantly (Figs. 9–10). The re-formation of the mucilage layer takes place similarly wherever the original mucilage layer is removed. This happens occasionally elsewhere than near the ends of the cell after abscission, as if an effort to accomplish this were initiated in an abnormal position. Here also it is at first free of rods, but these appear shortly afterwards.

The whole matter compares closely to the process of abscission of the type accompanied by growth of the cells involved, well exemplified in Mirabilis (Lloyd, 1916). Here also the dissociation of the wall substance is begun in the outermost layers, but does not affect the middle lamella, and here also growth continues at first with a very delicate wall surrounding the protoplast.

This action at some distance from the protoplast, that is, the generally understood ectoplasmic layer, requires some explanation. Were the action the result of an enzyme diffusing out from the protoplast, we should expect it to act as it goes. The fact is that, on the contrary, the hydrolytic action takes place first at the outermost limits of the wall. It is therefore more logical to infer — if an inference may be made at all — that the enzyme arises where it first makes itself evident. This view requires recourse to the idea of the cell-wall as included within the limits of the living cell. It is worth while here to indicate that one may find cases of living Spirogyra cells of which a portion

of the cell-wall has become incapable of any modification by the organism, and may be described as dead (Fig. 8). The fact that the rods arise secondarily in the outer cell-wall layer has a similar purport.

On the other hand, abjection finds its parallel in the mosses, if we accept Correns' (1899) description as complete. Correns recognizes two methods of cell disjunction in this group of organisms to which he gives the terms schizolysis and rhexolysis. The former is the splitting apart of the cells along the line of the middle lamella, most cases falling into this category; the latter, far more rare, consists in fracture across the cell, looking as if cut clean with a knife. He cites Dicranum as fulfilling this description. So far as I am aware, the closest parallel is to be found in Oedogonium and similar organisms, but the parallel is far from complete, since the protoplast with its immediately investing wall remains intact, whereas we lack precise information as to what happens in the mosses.

Schizolysis has been recognized as occurring also in the petals of Geranium, by Fitting (1911), though he does not call it so. He ascribed the abjection of the petals to changes in the curvatures of the cell-walls consequent on rapid changes in volume of the cells involved by the heightening of turgor, such changes being the more effective the smaller the cells, those of the tissues involved being very small indeed. The changes in curvature lead to the tearing of the middle lamella, and the springing, thus permitted, of the wall and cuticula. These changes can be induced within the short period of 25 to 50 seconds. It may be recalled here that Benecke could procure abjection in Mougeotia experimentally also by increasing turgor as well as by decreasing it.

Incidentally to this study I have been inclined to take cognizance of the apparently unusual and exceptional case of *S. colligata*. It would seem that the difference between this species and those in general is a quantitative one. It is at all events difficult to see that the H-piece in *S. colligata* is very much different from that in the species which have notably thick walls, as, for example, in that furnishing the material for the paper.

SUMMARY

1. Motion photomicrography has been used to study cell disjunction in *Spirogyra Weberi.*

2. In both large and small species of Mougeotia the intercellular gelatinous material is a mechanical factor in abjection. The older conception of the way in which the mechanism of abjection works is found inadequate, and a revised explanation is submitted.

3. Abjection in *S. Weberi* is not accompanied by any inward unfolding of the transverse wall of the discarded cell. It may remain unaffected, or, like that of the active cell, it may be evaginated. A revised explanation of the behavior of the transverse walls during abjection is submitted.

4. Abscission occurs in *S. nitida.* It begins by the breaking down of the outermost layer (mucilage layer), and progresses inwardly. The rods remain unaffected. The cellulose layers are then changed, the alteration passing around the end of the cell, setting free the H-piece.

5. Abjection in Spirogyra appears to be the same process as occurs in the mosses (schizolysis of Correns).

6. Abscission appears to parallel in all points the process of abscission in higher plants, in which abscission proceeds as in Mirabilis.

7. The H-piece is present in Spirogyra, and *S. colligata* appears to be a somewhat more specialized condition.

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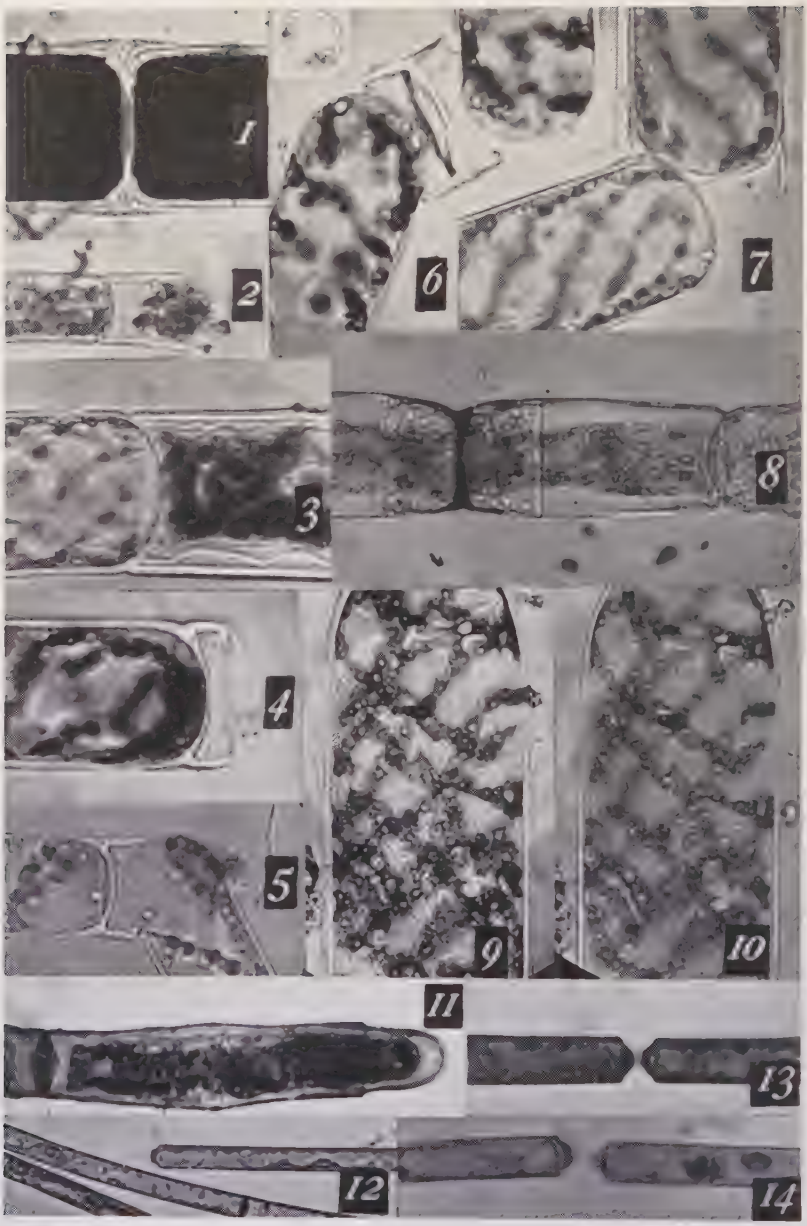
PLATE XIX

PLATE XIX



## DESCRIPTION OF PLATE XIX

SPIROGYRA NITIDA (Figs. 1–10)

FIG. 1. H-piece standing out strongly after treatment with sulphuric acid.

FIG. 2. The thickening of the cell-wall immediately on release of turgor pressure brought about by cross-cutting the filament.

FIG. 3. Twenty-two hours later than Figure 2. Note (*a*) the hydration of the innermore lamellae of the cut cell-wall; (*b*) the degree of progress attained in abscission; the outer membranes disintegrated further than the inner.

FIG. 4. A living cell has cast off and the next adjoining cell now shows the progressive change in the cell-wall somewhat further advanced than in Figure 3. Note the inward curling of the edge of the H-piece due to the less extensibility of the inner layers as observed by Strasburger.

FIG. 5. The extensibility of the delicate inner cell-wall left after abscission; consequent bulging under the rift in the abscission zone and at the end of the cell already freed.

FIG. 6. Both cells free at the same time; the H-piece is completely set free. The swollen inner cellulose layers can be seen in a distorted position at the end of the upper cell. Inset. — H-piece viewed along the axis.

FIG. 7. As a result of displacement before abscission had progressed very far, the middle lamella can be seen still sticking to the cellulose wall proper of the cells, first to one side, then to the other.

FIG. 8. A case in which the cell-wall died before the protoplast. Death overtook the H-piece and the adjoining region of the wall, so that it was no more capable by stretching of accommodation to the growing cell.

FIGS. 9, 10. Before and after treatment with 1 per cent sulphuric acid. The outer mucilage layer loses its outer contour when treated with this reagent, while the basal membrane and rods persist. A few rods are visible in the new mucilage layer and these can be seen also after treatment with sulphuric acid.

MOUGEOTIA (Figs. 11–14)

FIG. 11. A large species of Mougeotia showing the gelatinous content of the intercellular space between the contiguous cells. Abjection of the cell has been followed by growth. Stained with ruthenium red.

FIG. 12. A small species of Mougeotia showing the gelatinous intercellular mass still adherent to the end of the cell after abjection. Ruthenium red.

FIG. 13. Two cells after abjection adhere by the intercellular gelatinous material. Ruthenium red.

FIG. 14. A similar case with the gelatinous material stretched out. Ruthenium red.

# HOLLOW HEART IN POTATOES

HENRY CARLETON MOORE

POTATO hollow heart, characterized by a lens-shaped hole surrounded by brownish discoloration of the flesh at the center of the affected tuber, is well known to growers, dealers and consumers. The loss caused by this defect, in preparing potatoes for the table, has long been a source of annoyance to the housewife and a subject of severe criticism by consumers generally. Not until the last three or four years, however, has this trouble been considered of serious economic importance. The establishment of standard potato grades throughout the country and the rigid inspection of potatoes by federal and state inspectors have forcibly brought hollow heart to the attention of all interested in the potato industry.

According to the requirements for the U. S. No. 1 grade, not more than six per cent by weight of the potatoes sold under this grade may show hollow heart. In the 1924 and 1925 shipping season many cars of potatoes from Michigan and other northern states were rejected because of excessively high percentages of hollow heart. Since this defect prevented the sale of the potatoes as U. S. No. 1 grade, it resulted in their being sold in many cases as U. S. No. 2 grade, with serious financial loss to the shippers.

Hollow heart is not caused by fungus or bacterial pathogenes. It is believed to be a physiological trouble caused by conditions favoring excessively rapid development of the tuber. Without a doubt, the amount and distribution of rainfall during the growing season have a direct bearing on tuber development and the presence or absence of hollow heart.

In 1924 this disorder was of serious concern in all sections of Michigan, although in 1925 it was of little consequence and was restricted to a few sections. The average rainfall from June to

September inclusive in 1924 was 3.26 inches, and for the same period in 1925 it was 2.91 inches, a difference of only 0.35 inches. By months, however, the rainfall of 1924 exceeded that of 1925 by the following amounts: June, 0.82 inches; July, 0.21 inches; August, 1.29 inches. The September rainfall in 1924 was 0.89 inches less than that of September, 1925. It is believed that the rainfall in August, 1924, which was 0.77 inches above normal, was an important factor in causing serious hollow heart injury. The rainfall of August, 1925, which was 0.52 inches below normal, prevented excessive tuber development and made hollow heart a negligible factor. Bin inspection reports of certified seed potatoes in the fall of 1925 showed practically no hollow heart in the northwestern counties of the Lower Peninsula, where drought conditions prevailed during the latter part of July and thoughout August. In the central and southern counties, where rainfall was about normal, a small amount was found.

Further evidence that rainfall is an important factor in causing hollow heart was obtained from a field experiment conducted in the summer of 1925 in which four plots of potatoes were irrigated with an automatic sprinkler, while the remaining four plots received no irrigation. A study of Table I shows that the irrigated Plots 2 and 4 of the May 30 planting had an average of 10.37 per cent of hollow heart compared with 1.09 per cent for Plots 1 and 3, which were not irrigated. In the June 25 planting the irrigated Plots (6 and 8) averaged 3.81 per cent hollow heart and Plots 5 and 7 not irrigated, 0.85 per cent hollow heart.

The first application of water to Plots 2 and 4 was made July 14; other applications were made at frequent intervals up to September 26. Plots 6 and 8 were first watered on August 19 and received frequent applications until September 26. The total amount of water applied to the irrigated plots was as follows: Plots 2 and 4, four inches; Plots 6 and 8, 2.7 inches; Plots 2 and 4 of the early planting received approximately 70 per cent of the irrigation water in August. It is thought that the heavy water applications made in this month were largely responsible for the increase of hollow heart in the irrigated plots.

The rainfall in August was 2.13 inches, 0.50 inches below the normal precipitation. In the late planting, Plots 6 and 8 received 1.4 inches of irrigation water in August and one inch in September. The total rainfall for September was 3.88 inches, which was 1.26 inches above normal precipitation. The low percentages of hollow heart in the late planting are not so significant, since the irrigated plots in this planting received less water than those in the May 30 planting.

In both the early and late plantings, irrigated plots outyielded those not irrigated. In the early planting, the average size of the tubers and the percentage of oversized potatoes was greater in the irrigated plots. Potatoes of the late planted plots averaged 2.2 ounces smaller than those in the early planting and had no appreciable amount of oversized tubers.

In this experiment, the 36-by-18-inch spacing gave an average increase in yield over the 36-by-36-inch spacing of 34.6 per cent for the early planting and 18.1 per cent for the late planting. The average percentage of hollow heart in the early planting with 36-by-36-inch spacing was 9.35 compared with 2.65 per cent for the 36-by-18-inch spacing. The late-planted 36-by-36-inch spacing gave an average percentage of hollow heart of 3.39, while the 36-by-18-inch spacing averaged 1.26 per cent hollow heart. This should be significant to potato growers since this result indicated that closer spacing reduces the amount of hollow heart and increases the yield.

Further information on the relationship of spacing distance to hollow heart development was obtained during the 1924–25 shipping season, when ninety-five lots of certified Russet Rural seed potatoes were examined for hollow heart. The data obtained were compared with the field inspection reports which stated in detail the cultural conditions under which these lots were grown. Generally those lots showing the least hollow heart came from fields where close spacing was practiced. Fields in which the feeding area per hill was greater than 600 square inches had the largest number of lots showing hollow heart. In this study it was found also that the amount of hollow heart varied inversely with the percentage of stand. Where there was

SUMMARY OF DATA OBTAINED FROM HOLLOW HEART FIELD EXPERIMENT

| | Plot No. | Treatment | Total lb. | Spacing distance | Total bush. per acre | No. lb. hollow | Percentage hollow by weight | No. lb. oversized | Percentage oversized | No. tubers in 20-lb. sample | Av. weight tubers (oz.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Planted May 30 | 1 | not irrigated | 230 | 36 by 18 | 307 | 0 | 0 | 7.9 | 3.43 | 57 | 5.6 |
| | 2 | irrigated | 215.7 | 36 by 36 | 290 | 33.5 | 15.43 | 16 | 7.41 | 32 | 10 |
| | 3 | not irrigated | 183 | 36 by 36 | 244 | 6 | 3.28 | 5.2 | 2.84 | 44 | 7.3 |
| | 4 | irrigated | 310.5 | 36 by 18 | 412 | 16.5 | 5.31 | 16 | 5.15 | 48 | 6.7 |
| Planted June 25 | 5 | not irrigated | 188.5 | 36 by 18 | 251 | 0 | 0 | 0 | 0 | 72 | 4.4 |
| | 6 | irrigated | 206.2 | 36 by 36 | 275 | 10.5 | 5.09 | 3.9 | 1.89 | 57 | 5.6 |
| | 7 | not irrigated | 187.5 | 36 by 36 | 250 | 3.2 | 1.7 | 3.9 | 2.08 | 56 | 5.7 |
| | 8 | irrigated | 276.5 | 36 by 18 | 369 | 7 | 2.53 | 1 | .36 | 60 | 5.3 |

Number of rows per plot, 6; date of first killing frost, Oct. 10; size of plots, 60 by 18 feet; date of harvesting, Oct. 21; variety, Russet Rural

a 90 per cent stand or better, there was considerably less than the average amount of hollow heart.

At present there is no evidence to indicate that hollow heart is hereditary or confined to certain strains. In the southern states it is seldom observed, though it is quite common in the seed brought from the north. There is a difference, however, in varietal susceptibility to hollow heart. Throughout the northern states, potatoes of the Rural type, such as Rural New Yorker No. 2, Carmen No. 3, Russet Rural, etc., are the most severely affected. Other varieties seriously affected are Irish Cobbler, Early Ohio and Spaulding Rose. Green Mountain, Russet Burbank, Triumph, Peach Blow and Downing are generally very free from hollow heart.

It is the opinion of some Michigan growers and dealers that the Russet Rural variety is more susceptible to hollow heart than the White or Smooth Rurals. This opinion may be erroneous, since their observations have been confined mostly to the Russet Rural variety which constitutes approximately 90 per cent of Michigan's late potato crop. A survey made in the spring of 1919 to determine the relative susceptibility of these varieties to hollow heart did not show any difference between them. Counts on hollow heart, made during the cutting of seed for strain tests in 1925, showed approximately the same percentages of hollow heart in Russet Rural, White Rural and Irish Cobbler. The few lots of Green Mountain seed cut had no hollow heart.

Other factors that may affect hollow heart, such as temperature, type of soil, chemical fertilizers, cultivation, etc., are being studied in greenhouse and field tests and more information may be available in the near future that will help growers to overcome this defect in their potato crop. In the meantime, it is believed that hollow heart in Michigan potatoes can be materially reduced if growers will follow the cultural methods that are generally recommended for the production of good yields of high quality potatoes. Briefly these are:

1. Improve the moisture condition of the soil by preceding the potato crop with alfalfa, sweet clover or some other legume in the rotation. Plow in the fall or very early in the spring, making

the seed bed deep and mellow. By frequent harrowing keep the soil in a fine mellow condition until planting time.

2. Apply stable manure several months previous to planting. Supplement the stable manure with a high analysis commercial fertilizer applied broadcast or in the furrow.

3. Plant the best seed available — preferably certified seed, which has been treated with corrosive sublimate for the control of scab, black scurf and black leg. This precaution will help insure a good stand of healthy plants.

4. Use large seed pieces ($1\frac{1}{2}$ to 2 ounces) and plant the hills as close as soil moisture and fertility conditions warrant for a satisfactory crop. Generally on fertile soils the spacing should be 36 by 18 inches or less. Some growers, on very fertile soils are getting the best results by planting at 36 by 12 inches. Under most conditions 36-by-36-inch spacing should be condemned, since the potatoes usually grow too large and rough and many of them are hollow.

5. Plant sufficiently early so that the potatoes will mature before the first frost. Immature potatoes bruise easily in handling, become dark colored and are undesirable from a market standpoint.

6. Give shallow cultivation until the plants are in blossom to kill weeds and grass and to keep the soil in a mellow condition. Late cultivations are of little benefit and often do much injury to the root system.

Frequent sprayings with arsenicals and bordeaux mixture should be given to ward off insect and foliage disease attacks. Every effort should be made to keep the plants in a thrifty condition.

7. Before placing the crop on the market, grade it carefully to conform with the Michigan standard potato grades. Special precaution to eliminate hollow heart should be observed. All ill-shaped, rough or oversized potatoes should be sorted out, since usually hollow heart is most common in this class of stock.

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# AN ECOLOGICAL STUDY OF HOGBACK BOG, CHEBOYGAN COUNTY, MICHIGAN

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HOGBACK BOG is a small peat bog near the Biological Station of the University of Michigan, Cheboygan County, Michigan. It is about one eighth of a kilometer west of Carp Creek and its waters are 5.3 meters higher. It is 64 meters wide and 107 meters long. The entire mat is grounded and the greatest depth to sand is barely a meter. In spite of its situation near Carp Creek, there is no drainage. This is due to the impervious clay bottom. The small amount of standing water comes from rainfall and from seepage from the surrounding ridge. The water is decidedly acid, having a hydrogen ion concentration of 3.3 pH.[1]

Because of the large number of pines and pine association plants found at its edge, it is believed that this bog was once a depression in a pine forest. Evidently the depression was lumbered and burned, for there are a great many logs underlying the vegetation of the bog and traces of charcoal are found in the peat. Some of the pines were left at the edge. After the depression had been cleared, water gathered in it and an impervious clay bottom was formed. Because of this, bog conditions developed and Chamaedaphne covered the area (see Pl. XX, Fig. 1).

No fires have been noted in the bog during the past fifteen years. The development of the bog has been retarded, however, in another way. As late as 1911 Sphagnum was removed from the central portion of the bog for commercial purposes. During this operation the Chamaedaphne was cut and raked out

* The work was done at the Biological Station of the University of Michigan under the direction of Professor Frank C. Gates.

[1] Determination by Harold Brown, July 6, 1925.

(see Pl. XX, Fig. 2). This left an open pond in the center in which there has been as much as 30 centimeters of water. It is not known whether a *Carex lasiocarpa* mat has ever formed, but in 1916 a Sphagnum entered the pond, and a year or two later covered it. Two years after the appearance of the Sphagnum, *Eriophorum tenellum*, *Eriophorum angustifolium* and *Dulichium arundinaceum* were found in it. In 1920 there was quite a display of Eriophorum, but by 1921 Dulichium had become very abundant and now dominates in the open spaces.

Surrounding these open spaces and covering fully one third of the bog is the Chamaedaphne association. This association should push out into the open space rapidly, as the open space is practically grounded and the floor of the bog is covered with logs for Chamaedaphne to creep on. This has not been the case, however. The Chamaedaphne has pushed out very slowly since the bog has been under observation. One reason may be that the Chamaedaphne is infested by insects.

At the outer extent of the Chamaedaphne the high-bog shrub association is present, represented by *Nemopanthus mucronata* and *Aronia arbutifolia*. In the last three years, because there have been no fires, this association has been coming in rapidly, especially in the west and northwest portions of the bog.

The trees surrounding the bog belong to two distinct associations, the pine association as represented by *Pinus strobus* and *Pinus resinosa*, and a Picea-Larix association. The pine association is largely in the west and northwest area of the bog and a majority of the trees are twenty-five to fifty years of age. Pines of all ages, however, are scattered in and around the entire bog. The Picea-Larix association dominates in the southeast part. Only a very few can be considered more than fifteen years of age. Larix is much less numerous than Picea.

The vegetation of the Hogback Bog may be divided into the following associations: Sphagnum, Dulichium-Eriophorum, Chamaedaphne, High-bog shrub, Larix-Picea, Pine.

In the center, where the Chamaedaphne has been removed, Dulichium, Eriophorum and Sphagnum grow. With these several fungi are present. The bulk of the mat is made up of

species of Sphagnum. Sphagnum grows very quickly in sun or shade and forms a dense mat, as it keeps growing upward. It holds water, turning it acid; it is also a good peat former.

Growing among the Sphagnum in the acid water are *Eriophorum angustifolium* and *Dulichium arundinaceum*. Dulichium replaces Sphagnum, developing after the Chamaedaphne is locally removed.

Surrounding this association is the Chamaedaphne association which covers one third of the bog. It is characterized by *Chamaedaphne calyculata* and Sphagnum. Before its removal, it covered the entire area now occupied by the Dulichium-Eriophorum association. Logs which are left from the lumbering underlie the vegetation, and serve as a support upon which the Chamaedaphne can reënter more quickly. Progress, however, has been very slow. Chamaedaphne is well adapted as a dominant species as it has hard leathery leaves and is capable of existing in acid conditions. Its rapid growth and spread are due to vegetative reproduction and it is a good peat former.

At the edge of the Chamaedaphne association, the high-bog shrub association is invading as rapidly as the bog conditions permit. Since the mat is grounded and the bog quite dry, this association has spread quite rapidly. Its dominant species differs from the low-bog shrubs in their greater height, less vigorous vegetative reproduction, and more mesophytic tendencies. These shrubs are not characterized by hard, leathery leaves. The representatives of this association in Hogback Bog are *Nemopanthus mucronata, Aronia arbutifolia* and a very few plants of *Ilex verticillata*.

On the southeast edge of the bog a Picea-Larix association is dominated by *Picea canadensis*. A tree count showed twenty-one small and sixty-four large *Picea canadensis* and one small and seven large *Larix laricina*.

*Picea canadensis* is spreading through the high shrubs and some seedlings are invading the Chamaedaphne. All the Picea seem to be thriving, but there are only a few of the Larix and these are not thriving. Two of them have invaded the center of the bog, but they are not healthy and probably will not live long.

Entirely surrounding the bog is found the Pine association. Though some pines are found on all sides of the bog, they are more numerous on the north. As shown by a tree count of all the pines within the bog, there were 74 large and 4 small *Pinus strobus*, 29 large and 7 small *Pinus resinosa*. This would show that the pines have the ability to live and reproduce within it. Though *Pinus strobus* is now dominating, *Pinus resinosa* seems to be reproducing more plentifully.

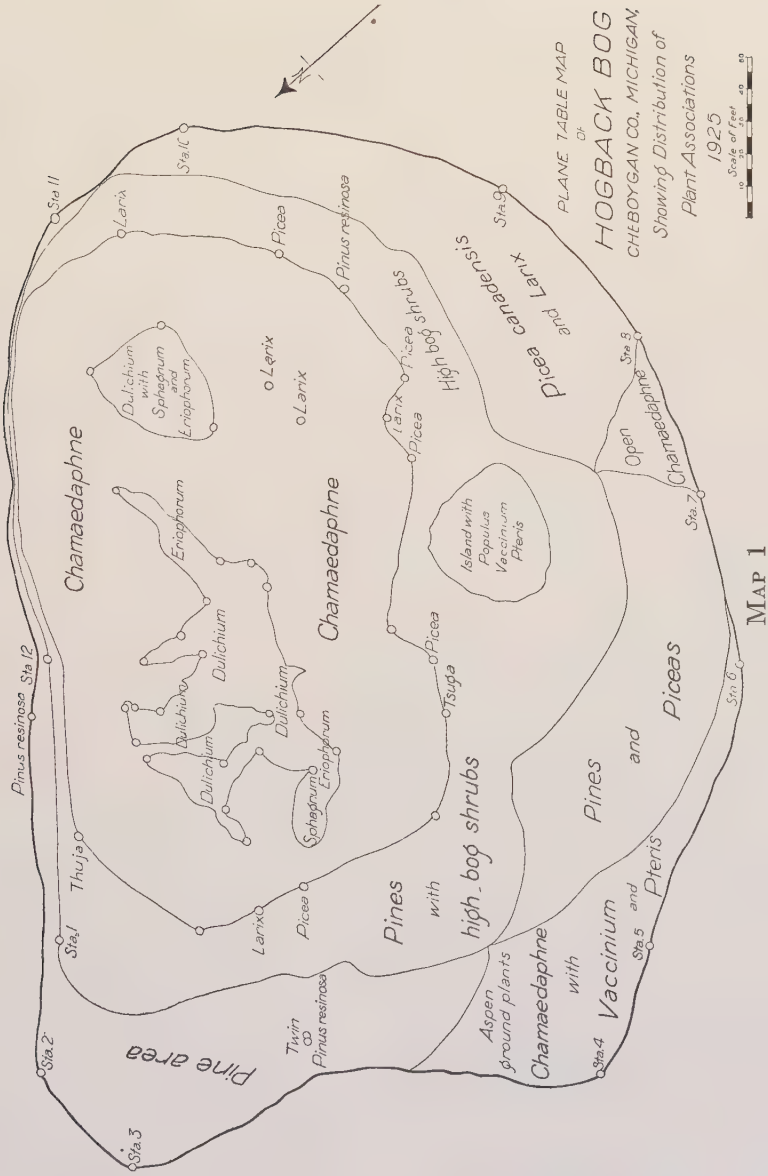
Most of the ground plants in this association are common pine land plants such as *Gaultheria procumbens, Epigaea repens, Unifolium canadense* and *Cornus canadensis*. There are several typical aspen ground plants such as *Pteris aquilina, Vaccinium canadense, Vaccinium angustifolium* and aspen mosses among the pines, especially on the outer edge. This mixture of ground plants indicates a disturbed condition. The presence of so many pines in a bog is very unusual. The explanation lies in the probable history of the bog as given above.

Although the tree count shows that the pines are not reproducing rapidly, there are a number of trees of all ages here. The pines do not belong to a regular bog succession, but they are thriving well. Unless lumbering or fire disturbs them, they will play an important part in the succession of the area.

Though these are the important associations represented in the bog, there are representatives of other associations also. The Thuja association is represented by one small tree of *Thuja occidentalis* found between Stations 1 and 12 (see Map 1). On the opposite side of the bog, one small *Tsuga canadensis* is found on a hummock. Since a number of hemlocks are growing along Carp Creek, the seed of this one probably came from there.

This entire area is surrounded by aspens. Several stray species such as *Pteris aquilina, Betula papyrifera, Populus tremuloides* and *Populus grandidentata* occur in the bog proper. On a raised area in the western part of the Chamaedaphne association, there is an aspen island, some 9 by 11 meters in size.

Southwest of the Hogback Bog is a smaller bog. It is grounded and even drier than the Hogback Bog. The central part is occupied by Chamaedaphne and Sphagnum. Surrounding


PLANE TABLE MAP
OF
HOGBACK BOG
CHEBOYGAN CO., MICHIGAN,
Showing Distribution of
Plant Associations
1925
Scale of Feet
Chamaedaphne
Dulichium with Sphagnum and Eriophorum
Eriophorum
Dulichium
Sphagnum
Island with Populus Vaccinium Pteris
High bog shrubs
Picea canadensis and Larix
Open Chamaedaphne
Pines with high bog shrubs
Pines and Piceas
Aspen ground plants
Chamaedaphne with Vaccinium and Pteris
Pine area
Twin Pinus resinosa
Pinus resinosa
Larix
Picea
Thuja
Tsuga
Sta. 1
Sta. 2
Sta. 3
Sta. 4
Sta. 5
Sta. 6
Sta. 7
Sta. 8
Sta. 9
Sta. 10
Sta. 11
Sta. 12

MAP 1

this are the high-bog shrubs represented by *Aronia arbutifolia* and *Nemopanthus mucronata*; several grasses, and three species of Polytrichium. One Picea and several pines were found in the vicinity of the bog. In the bog were two pine seedlings and many small trees of *Populus tremuloides*. The aspen species were dominant.

Provided fires do not interfere in the bog, the Chamaedaphne will probably recover the central portions and the high-bog shrubs will invade the Chamaedaphne. When the bog is dry, Picea and Larix may enter the central portion. If the bog becomes sufficiently built up, the pines may overrun it and it will be restored to its former state; but if the Sphagnum retains a high water-level, the succession would be very slow or may not take place.

## SUMMARY

1. Hogback Bog in Cheboygan County, Michigan, was apparently once a depression in a pine forest.

2. The mat of the bog is now grounded and in dry years the bog is practically dry.

3. Lumbering and fires have not disturbed the bog recently, but Sphagnum has been removed for commercial purposes.

4. The vegetation of Hogback Bog can be divided into the following associations, Sphagnum-Dulichium-Eriophorum, Chamaedaphne, High-bog shrub, Picea-Larix and Pine.

5. Eventually by spreading of the pines from the northwest portion of the bog, the entire bog is likely to become pine land again.

PEAT READINGS

The following peat readings were taken in Hogback Bog in the Dulichium and Chamaedaphne from Station 12 to Station 5:

| | Distance northwest from Station 12 (meters) | Depth to sand (meters) | Sample |
|---|---|---|---|
| 1. | 5 | 0.6 | Sphagnum<br>Decaying plant remains<br>Charcoal<br>Peat and sand<br>Sand |
| 2. | 7.5 | 0.6 | Undecayed Sphagnum<br>Decaying Sphagnum<br>Sand |
| 3. | 10 | 0.9 | Sphagnum<br>Little decaying plant remains<br>Sand with little peat<br>Sand |
| 4. | 12 | 0.6 | Sphagnum<br>Decaying plant remains<br>Sand |
| 5. | 14.5 | 0.6 | Sphagnum<br>Sand |
| 6. | 17 | 0.6 | Sphagnum and decaying plant remains<br>Sand |

## LIST OF SPECIES IN HOGBACK BOG

TREES

Acer rubrum
Betula papyrifera
Larix laricina
Picea canadensis
Pinus resinosa
Pinus strobus
Populus grandidentata
Populus tremuloides
Quercus borealis (seedling only)
Thuja occidentalis
Tsuga canadensis

HIGH SHRUBS

| | |
|---|---|
| Alnus incana | Nemopanthus mucronata |
| Amelanchier canadensis | Salix sp. |
| Aronia arbutifolia | Viburnum cassinoides |
| Ilex verticillata | Viburnum lentago |

LOW SHRUBS

| | |
|---|---|
| Chamaedaphne calyculata | Rubus villosus |
| Epigaea repens | Vaccinium canadense |
| Gaultheria procumbens | Vaccinium angustifolium |

HERBACEOUS PLANTS

| | |
|---|---|
| Aster laevis | Habenaria obtusata |
| Circaea alpina | Melampyrum lineare |
| Coptis trifolia | Osmunda cinnamomea |
| Cornus canadensis | Potentilla palustris |
| Dulichium arundinaceum | Pteris aquilina |
| Eriophorum angustifolium | Trientalis americana |
| Eriophorum tenellum | Unifolium canadense |

MOSS SPP.

| | |
|---|---|
| Dicranum flagellare | Polytrichum commune |
| Dicranum rugosum | Sphagnum spp. |
| Dicranum scoparium | |

University of Michigan Biological Station
Cheboygan, Michigan

## EXPLANATION OF PLATE XX

Fig. 1. A general view of Hogback Bog from the southeast, showing the high-bog shrub around the edge, the Chamaedaphne through the center, and the pine–high-bog shrub area in the immediate background. Aspens may be seen in the extreme background. (Photograph by F. C. Gates, 1925)

Fig. 2. A view in the center of the Chamaedaphne area, showing the part from which Sphagnum has been commercially removed, now grown up largely with Dulichium and bordered on all sides by Chamaedaphne. (Photograph by Sigler and Woollett, 1925)

PLATE XX

FIG. 1

FIG. 2

# THE ALGAL COLLECTION OF A SINGLE FISH*

LEWIS HANFORD TIFFANY

IN PREVIOUS papers (6, 7, 8) attention has been called to the desirability of using the young gizzard shad, *Dorosoma cepedianum* Le Sueur, as a collector of the plankton algae. Recently through the kindness of Professor Carl L. Hubbs of the Museum of Zoölogy, University of Michigan, there was placed in the writer's hands a young gizzard shad that apparently sets a unique record for the number of different species and varieties of algae found in an identifiable condition in the digestive tract of any young fish. This fish measured fifty millimeters from the point of the snout to the base of the caudal fin, and was collected at the mouth of the River Raisin, near Munroe, Michigan, on October 23, 1920.

It seems that the River Raisin is a highly polluted stream, most of the current of which passes out through the ship canal. This particular gizzard shad was caught, however, in the mouth of the river proper. Without this knowledge it would be difficult to account for the number of algae, particularly of the Chlorophyceae, given in the list. The Bluegreens and the Diatoms might occur in streams of considerable pollution, but the Chlorophyceae would scarcely be found there. Such diversity of habitat is doubtless responsible for the variety and range of the algal food of the fish.

The species and varieties of algae identified from this young gizzard shad numbered 57, distributed in the following groups: 11 Myxophyceae, 3 Euglenidae, 1 Phaeophyceae, 2 Heterokonteae, 13 Bacillariae, and 27 Chlorophyceae. These algae, further, constitute 6 classes, 7 orders, 10 families, 28 genera, 47 species, and 10 varieties of plants.

* Paper from the Department of Botany, The Ohio State University, No. 165.

The majority of the algal forms are apparently unrecorded for the State of Michigan, although some have been noted by Transeau (10), and the list is consequently appended in full. The list furnishes another example of the algal diversity of some bodies of water and indicates an advanced position of the gizzard shad among its piscatorial relatives as a collector of the plankton algae.

## Systematic Account of Algal Forms

### MYXOPHYCEAE (Bluegreen algae)

1. *Chroococcus limneticus* Lemm.
2. *Chroococcus limneticus* Lemm. var. *subsalsus* Lemm.
3. *Chroococcus turgidus* (Kuetz.) Naeg.
4. *Merismopedia elegans* A. Br.
5. *Merismopedia glauca* (Ehr.) Naeg.
6. *Merismopedia tenuissima* Lemm.
7. *Coelosphaerium kuetzingianum* Naeg.
8. *Coelosphaerium naegelianum* Unger.
9. *Microcystis aeruginosa* Kuetz.
10. *Microcystis aeruginosa* Kuetz. var. *major* (Wittr.) G. M. Smith.
11. *Oscillatoria prolifica* (Grev.) Gomont.

### EUGLENIDAE

1. *Euglena spirogyra* Ehr.
2. *Euglena sp.* (?)
3. *Phacus longicauda* (Ehr.) Duj.

### PHAEOPHYCEAE (Brown algae)

1. *Dinobryon setularia* Ehr.

### HETEROKONTEAE (Yellow-green algae)

1. *Botryococcus braunii* Kuetz.
2. *Botryococcus protuberans* var. *minor* G. M. Smith.

### BACILLARIAE (Diatoms)

1. *Melosira varians* Ag.
2. *Melosira crenulata* (Ehr.) Kuetz.
3. *Melosira distans* (Ehr.) Kuetz.
4. *Melosira granulata* (Ehr.) Ralfs.
5. *Cymbella ventricosa* Kuetz.
6. *Cymbella cymbiformis* (Kuetz.) Bréb.
7. *Cymbella mexicana* (Ehr.) A. S.
8. *Cymbella affinis* Kuetz.

9. *Navicula cryptocephala* Kuetz.
10. *Navicula salinarum* Grün.
11. *Synedra pulchella* (Ralfs) Kuetz.
12. *Meridion circulare* (Grev.) Ag.
13. *Cocconeis placentula* Ehr.

CHLOROPHYCEAE (Green algae)

1. *Pandorina morum* Bory.
2. *Eudorina elegans* Ehr.
3. *Dictyosphaerium pulchellum* Wood.
4. *Westella linearis* G. M. Smith.
5. *Oocystis borgei* Snow.
6. *Oocystis pusilla* Hansg.
7. *Oocystis elliptica* W. West.
8. *Selenastrum westii* G. M. Smith.
9. *Kirchneriella obesa* (W. West) Schm. var. *major* G. M. Smith.
10. *Crucigenia rectangularis* (Naeg.) Gay.
11. *Scenedesmus bijuga* (Turp.) Lager.
12. *Scenedesmus bijuga* (Turp.) Lager. var. *alternans* (Reinsch) Borge.
13. *Scenedesmus bijuga* (Turp.) Lager. var. *flexuosus* (Lemm.) Coll.
14. *Scenedesmus quadricauda* (Turp.) Bréb.
15. *Coelastrum microporum* Naeg.
16. *Coelastrum reticulatum* (Dang.) Senn.
17. *Sorastrum spinulosum* Naeg.
18. *Pediastrum boryanum* (Turp.) Men.
19. *Pediastrum simplex* Ralfs.
20. *Pediastrum simplex* Ralfs var. *duodenarium* (Bailey) Raben.
21. *Pediastrum duplex* Meyen.
22. *Pediastrum duplex* Meyen var. *clathratum* (A. Br.) Lager.
23. *Pediastrum duplex* Meyen var. *reticulatum* Lager.
24. *Pediastrum tetras* (Ehr.) Ralfs.
25. *Tetraedron muticum* (A. Br.) Hansg.
26. *Tetraedron minimum* (A. Br.) Hansg.
27. *Tetraedron regulare* Kuetz.

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# DISTRIBUTION OF THE CRUCIFERAE IN MICHIGAN

BRANSON A. WALPOLE

MY PURPOSE in this paper is to make a survey of the mustards found in Michigan. It is intended to correlate with similar contributions for the state, Dr. H. T. Darlington's upon the Orchidaceae,[1] Miss Bertha E. Thompson's upon the Violaceae,[2] and Dr. L. A. Kenoyer's upon the Umbellales[3] and Ericales.[4] I have followed the plan and organization of these excellent papers because they will be used in compiling a new Michigan flora.

In the preparation of this report, I have made a careful study of all available herbarium material. I have consulted, in addition to my own personal collections, the herbaria of the University of Michigan, Michigan State College (formerly Michigan Agricultural College), Michigan State Normal College, Michigan Western State Normal College, the Grand Rapids Historical Museum, the Field Museum in Chicago, the private herbaria of Messrs. C. Billington of Detroit and C. W. Fallass of Petoskey. All available distribution lists were used in compiling the information gathered in this paper.

The nomenclature of the second edition of Britton and Brown's *Illustrated Flora of United States and Canada* is followed, except for the genus Brassica which is covered by L. H. Bailey's *The Cultivated Brassicas*, published in 1922.

I am indebted to Dr. E. A. Bessey and Dr. H. T. Darlington for advice and for many helpful suggestions in preparing this

[1] "Distribution of the Orchidaceae in Michigan," *Report of the Michigan Academy of Science*, 21. 239–261.

[2] "Distribution of the Violaceae of Michigan," *Papers of the Michigan Academy of Science, Arts and Letters*, 1. 167–184.

[3] "Distribution of the Umbellales in Michigan," *op. cit.*, 3. 131–165.

[4] "Distribution of the Ericales in Michigan," *ibid.*, 166–191.

distribution list, as well as for criticism and correction of the manuscript.

Few families of plants are of such great economic importance as the mustard family, not only because of the large number of troublesome weeds it contains, but also because of the fact that not a single unwholesome plant is found in it. Many species form well-known and excellent articles of food. Some of our worst weeds, however, most of which have been introduced into Michigan, belong to this family.

There have been reported in Michigan thirty-four genera, including eighty-one species. We have forty-nine species from Europe, twenty-eight native to America, and four from Asia.

A study of the distribution for the members of this family shows that the greatest number of mustards are found in the area of the state under cultivation. Southern Michigan has by far the most species represented. This is easily accounted for by the number of European species in this section of the state, the introduced species coming in by the importation of farm seeds and supplies. The writer believes many more species could be found in the Upper Peninsula if the territory should be investigated. Reports upon plants from this region are meager and those that have been made often lack specimens to verify the finding.

The striking feature of this family is the almost complete lack of forest species. The family as a whole inhabits the open fields, roadsides, banks of streams, or cliffs. A few species are shade-tolerant.

*Draba nemorosa*, *Draba aurea*, *Erucastrum nasturtiifolium*, *Hymenophysa pubescens* and *Lunaria rediviva* are rare local species. It is not very likely that these plants will spread rapidly to other similar parts of the state. The writer has never seen a specimen of *Draba nemorosa*, though it has been reported by two reliable botanists.

The typical species for the northern part of the state are *Arabis holboellii*, *Draba arabisans*, *Draba nemorosa*, *Draba aurea*, *Cardamine parviflora*, *Arbidopsis novae-angliae*, *Sophia pinnata*, *Sophia incisa* and *Sophia sophia*.

*Cakile edentula* is a plant of the sandy beaches. It is found along the entire coast-line of the Great Lakes. *Lepidium perfoliatum* represents a species that came into the state from the west. *Draba verna* appears from the states to the southwest.

The outstanding point is the recent arrival of so many species of mustards within the state's boundaries and such a wide distribution of these newcomers. From the standpoint of actual value or harm, the family is one of the most important of those represented.

## *CRUCIFERAE B.* Juss. (Mustard Family)

Annual, biennial, or perennial herbs, sometimes with woody base and watery acrid (or pungent) sap. Leaves alternate. Flowers perfect, racemose or corymbose; sepals 4, deciduous; petals 4 or rarely wanting, alternating with the sepals. Stamens 6, rarely only 2 or 4; the outer shorter, opposite the inner sepals. Ovary 2-celled by a septum which stretches across from the placentae, rarely 1-celled; style undivided or wanting; stigma entire or 2-lobed. Fruit a capsule, often greatly elongated, technically called a silique or, if short, a silicle. Seeds attached to both sides of the septum.

### ARTIFICIAL KEY TO THE GENERA REPRESENTED IN MICHIGAN

The Key is written to fit only those genera and species known to occur in Michigan and must not be expected to fit localities where other genera and species are present.

I. Pod dehiscent into 2 valves to the base
  A. Pods orbicular, globose, or oblong, or but little more than twice as long as wide, therefore silicles
    B. Silicles globose or flattened parallel with the septum; pods a little longer than wide
      C. Silicle not compressed
        D. Silicle obovoid or pear-shaped, many-seeded; flowers yellow ..... 5. Camelina
        D. Silicle globose or terete-oblong

Petals 2-cleft, silicles pubescent..... 2. Berteroa
Petals not 2-cleft, silicles glabrous
Flowers yellow..... 8. Radicula
Flowers white
Terrestrial; style short, less than 2 mm. long; pods globular..... 10. Armoracia
Aquatic; submersed leaves finely dissected; style 2 mm. long; pods ovoid... 11. Neobeckia
C. Silicle compressed or flat
E. Silicle many seeded..... 1. Draba
E. Silicle 2–8 seeded
Flowers yellow..... 4. Alyssum
Flowers white..... 3. Koniga
B. Silicle flattened at right angles to the septum
F. Seeds several in each cell of the silicle
G. Silicle triangular, cuneate, wingless; plants with branched hairs..... 6. Bursa
G. Silicle oblong or orbicular, winged all around; plants with hairs simple or none.. 15. Thlaspi
F. Seeds solitary in each cell
H. Silicle glabrous, winged all around or at the apex, rarely wingless
Petals small, equal in size.. 12. Lepidium
Petals small, unequal in size..... 13. Iberis
H. Silicle pubescent, wingless... 14. Hymenophysa
A. Pod elongated to linear, at least twice as long as wide, therefore a silique
I. Silique tipped with a short style or with style lacking
J. Seeds globose or oblong, wingless
K. Seeds in 2 rows in each cell
Flowers white; pubescence of simple hairs or wanting..... 9. Sisymbrium
Flowers yellow; pubescence of forked hairs.... 16. Sophia
K. Seeds in 1 row in each cell
L. Leaves dentate, dis-

sected, or pinnatifid
Pods appressed, narrowly conic..... 18. Erysimum
Pods divergent, linear-cylindric..... 19. Norta
L. Leaves entire or slightly toothed
Flowers yellow
Stems glabrous; sessile, clasping..... 20. Conringia
Stems appressed pubescent; leaves not clasping..... 17. Cheirinia
Flowers purple, purplish-white, or white
Flowers purple, large, 15–20 mm. broad.. 21. Hesperis
Flowers white or pink, small, 3 mm. broad. 22. Arabidopsis
J. Seeds flat, winged or wingless
M. Silique 4-angled; valves keeled; flowers yellow.... 23. Barbarea
M. Siliques flat or flattish; flowers white, pink, violet or purple
N. Valves of the silique nerveless; seeds wingless; pods elastically dehiscent
Stem 2–3-leaved, naked below; rootstocks covered with scales or teeth..... 26. Dentaria
Stem leafy below; rootstocks without scales or teeth..... 25. Cardamine
N. Valves of the silique 1-nerved or veiny; seeds winged or winged-margined; pods not elastically dehiscent..... 24. Arabis
I. Siliques produced into a beak beyond the valves
O. Beak conic or filiform, seedless
P. Silique terrete, flowers yellow
Seeds in 1 row..... 31. Brassica
Seeds in 2 rows..... 32. Diplotaxis
P. Silique much compressed,

flowers violet..... 27. Lunaria
O. Beak flat, 4-angled or 2-edged, containing 1 seed
Q. Valves of the pod with 1 strong nerve
Plants glabrous; seeds in 2 rows in each cell; pods long-beaked..... 29. Eruca
Plants more or less pubescent; seeds almost always 1-rowed in each cell; pods short-beaked.. 30. Erucastrum
Q. Valves of the pod with 3 strong nerves..... 28. Sinapis
II. Pods indehiscent, short or elongated
R. Pods globose and reticulated..... 7. Neslia
R. Pods elongated
S. Pods of 2 joints, separating at maturity; maritime herbs..... 34. Cakile
S. Pods not jointed but constricted between the seeds; not maritime herbs..... 33. Raphanus

## 1. Draba [Dill.] L. Whitlow-grass

(Greek name for some plant of the family)

Flowers white
Petals deeply 2-cleft..... 1. *D. verna*
Petals entire, toothed, or emarginate
Flowering stems leafy only below; pods broadly linear and straight; winter annual. 2. *D. caroliniana*
Flowering stems leafy throughout; pods elliptic-lanceolate and twisted; perennial..... 3. *D. arabisans*
Flowers yellow, sometimes fading to white
Pods glabrous; style none; petals notched and slightly exceeding the calyx; pedicels divaricately spreading in fruit; winter annual..... 4. *D. nemorosa*
Pods pubescent; style stout; petals twice the length of the calyx, entire or emarginate; pedicels erect; perennials..... 5. *D. aurea*

1. *Draba verna* L. ('of spring')
Spring Whitlow-grass

Restricted to the southern counties. Sandy hillsides. Naturalized from Europe. February–May

Specimens examined. — Van Buren Co. (H. S. Pepoon, 1903); Ingham Co. (W. J. Beal, 1886, and C. F. Wheeler, 1894); Ionia Co. (B. A. Walpole, 1924).

Reported from Wayne Co. (Dr. Lyons, 1904); Ionia Co. (I. W. Stacey).

2. *Draba caroliniana* Walt.
Carolina Whitlow-grass
Restricted to the southern counties. Sandy fields. Native. May–June

Specimens examined. — St. Clair Co. (C. K. Dodge, 1900); Clinton Co. (C. F. Wheeler, 1890); Kent Co. (E. J. Cole, 1892); St. Joseph Co. (G. D. Crossman, 1911); Kent Co. (C. W. Fallass, 1894).

Reported from Ionia Co. (W. J. Beal, 1904).

3. *Draba arabisans* Michx. ('like arabis')
Rock-cress; Rock Whitlow-grass
Restricted to Mackinac Island and Isle Royale. Apparently native. June–August

Specimens examined. — Mackinac Island (C. F. Wheeler, 1897, C. H. Hicks, 1889, and J. H. Ehlers, 1920); Isle Royale (G. A. Marr, 1868).

4 *Draba nemorosa* L. ('of the woods')
Wood Whitlow-grass
A northern species, not examined by the writer. Native. Summer

Reported from Gratiot Co. (Dr. Pitcher, 1904); Ingham Co. (W. J. Beal, 1904).

5. *Draba aurea* Vahl. ('golden')
Golden Whitlow-grass
Apparently rare in Michigan. Native. Summer

Specimen examined. — Mackinac Island (J. H. Ehlers, 1920).

### 2. Berteroa DC.

(Named in honor of C. G. Bertero, botanist of Piedmont)

*Berteroa incana* (L.) DC. ('hoary')
Hoary Alyssum
Over all the state in waste places. Adventive from Europe. June–September

Specimens examined. — Iosco Co. (W. J. Beal, 1902); Washtenaw Co. (J. W. Howlett, 1904); Genesee Co. (P. J. Vandercook, 1900); Ingham Co. (C. F. Wheeler, 1902); Ingham Co. (H. T. Darlington, 1916); Washtenaw Co. (B. A. Walpole, 1918); Livingston Co. (C. H. Kauffman, 1923); Oakland Co. (C. Billington, 1915); Sanilac Co. (H. F. Ogden, 1917); Manistee Co. (Frank Sandhammer, 1916); Jackson Co. (S. M. Isbell, 1915); Lenawee Co. (Jesse Mayer, 1912); Oceana Co. (R. H. Burton, 1915); Grand Traverse Co. (W. H. Pease, 1915); Newaygo Co. (Joe Endt, 1911); Emmet Co. (Wilbur Smith, 1911); Muskegon Co. (B. A. Walpole, 1924); Ionia Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Lenawee Co. (B. A. Walpole, 1924).

Reported from Kalamazoo Co. (M. A. C., 1913); Midland Co. (M. A. C., 1919); Hillsdale Co. (M. A. C., 1918); Monroe Co. (M. A. C., 1919); Shiawassee Co. (M. A. C., 1913); Montmorency Co. (M. A. C., 1917); Iron Co. (M. A. C., 1914); Branch Co. (M. A. C., 1920); Ionia Co. (M. A. C., 1920); Kent Co. (M. A. C., 1920); Luce Co. (M. A. C., 1921); Isabella Co. (M. A. C., 1921); Mecosta Co. (M. A. C., 1922); Charlevoix Co. (M. A. C., 1922); Clare Co. (M. A. C., 1924); Saginaw Co. (M. A. C., 1924); Oakland Co. (O. A. Farwell, 1910); Houghton Co. (O. A. Farwell, 1921); Macomb Co. (O. A. Farwell, 1922).

### 3. Koniga Adans.

(Named in honor of Charles Konig, curator of the British Museum)

*Koniga maritima* (L.) R. Br. ('seaside')

*Lobularia maritima* (L.) Desv.

Sweet Alyssum; Seaside Koniga; Madwort

Occasional throughout the state in sandy waste places. Introduced from Europe. Summer

Specimens examined. — Washtenaw Co. (M. W. Harrington, 1874); Gratiot Co. (C. A. Davis, 1893); Kent Co. (C. W. Fallass, 1894); St. Clair Co. (C. K. Dodge, 1911); Ingham Co. (B. A. Walpole, 1922).

Reported from Wayne Co. (O. A. Farwell, 1900); Keweenaw Co. (O. A. Farwell, 1904).

### 4. Alyssum [Tourn.] L.

(Greek, 'curing madness')

*Alyssum alyssoides* L. ('like Alyssum')

Yellow Alyssum

Distributed throughout the state in sandy waste places. Naturalized or adventive from Europe. Summer

Specimens examined. — Gratiot Co. (C. A. Davis, 1904); St. Clair Co. (C. K. Dodge, 1896); Genesee Co. (D. Clark, 1887); Ingham Co. (W. J. Beal, 1871); Washtenaw Co. (B. A. Walpole, 1918); Livingston Co. (J. H. Ehlers, 1920); Jackson Co. (A. J. Pieters, 1892); St. Clair Co. (C. Billington, 1915); Ionia Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1922); Kent Co. (E. J. Cole, 1894); Emmet Co. (C. W. Fallass, 1918).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); Ionia Co. (C. F. Wheeler, 1904); Clinton Co. (C. F. Wheeler, 1890); Bay Co. (G. M. Bradford, 1904); Oakland Co. (O. A. Farwell, 1912); Washtenaw Co. (O. A. Farwell, 1891); Keweenaw Co. (O. A. Farwell, 1895); Allegan Co. (O. A. Farwell, 1923).

### 5. Camelina Crantz.

(Greek, 'low flax')

| | |
|---|---|
| Glabrous or nearly so; flowering racemes several, slightly elongated; valves much swollen; pods 6–8 mm. long | 1. *C. sativa* |
| Pubescent; flowering racemes isolated; valves slightly swollen; pods 4–6 mm. long | 2. *C. microcarpa* |

1. *Camelina sativa* (L.) Crantz. ('sown or planted')

False Flax

Introduced as a weed in many parts of the state. From Europe. June–July

Specimens examined. — Washtenaw Co. (E. C. Allmendinger, 1867); St. Clair Co. (C. K. Dodge, 1912); Keweenaw Co. (O. A.

Farwell, 1884); Washtenaw Co. (L. A. Osband, 1893); Wayne Co. (Steven Pearl, 1914); Cheboygan Co. (C. W. Fallass, 1918); Emmet Co. (C. W. Fallass, 1918).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Kent Co. (E. J. Cole, 1901); Schoolcraft Co. (C. K. Dodge, 1915); Wayne Co. (O. A. Farwell, 1900); Genesee Co. (W. J. Beal, 1904); Macomb Co. (W. J. Beal, 1904); St. Joseph Co. (W. J. Beal, 1904); Bay Co. (W. J. Beal, 1904); Oakland Co. (O. A. Farwell, 1912); Lenawee Co. (M. A. C., 1914); Chippewa Co. (M. A. C., 1920); Ionia Co. (I. W. Stacey); Washtenaw Co. (O. A. Farwell, 1891); Tuscola Co. (C. K. Dodge).

2. *Camelina microcarpa* Andrz. ('small-fruited')
Small-fruited False-flax

Distributed throughout the state in waste places. Naturalized or adventive from Europe. May–July

Specimens examined. — Washtenaw Co. (C. D. La Rue, 1915); Cheboygan Co. (J. H. Ehlers, 1917); Washtenaw Co. (B. A. Walpole, 1919); Wayne Co. (Howard Colby, 1915); Isabella Co. (C. E. Smithers, 1914); Lapeer Co. (E. A. Bessey, 1912); Oakland Co. (E. M. Ordway, 1912); Oakland Co. (C. Billington, 1914); Kent Co. (George Hannah, 1894); Clare Co. (B. A. Walpole, 1924); Ingham Co. (B. A. Walpole, 1921); Muskegon Co. (B. A. Walpole, 1924); Allegan Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1922); Clinton Co. (B. A. Walpole, 1924).

Reported from Oakland Co. (O. A. Farwell, 1912); Alger Co. (M. A. C., 1917); Kalamazoo Co. (M. A. C., 1913); Livingston Co. (M. A. C., 1918); Branch Co. (M. A. C., 1918); Saginaw Co. (M. A. C., 1913); Montcalm Co. (M A. C., 1913); Genesee Co. (M. A. C., 1912); Gratiot Co. (M. A. C., 1918); Alcona Co. (M. A. C., 1915); Clare Co. (M. A. C., 1917); Jackson Co. (M. A. C., 1911); Tuscola Co. (M. A. C., 1911); Barry Co. (M. A. C., 1920); Clinton Co. (M. A. C., 1920); Monroe Co. (M. A. C., 1921); Gladwin Co. (M. A. C., 1922); Chippewa Co. (M. A. C., 1922); Huron Co. (M. A. C., 1924); Allegan Co. (O. A. Farwell, 1923).

### 6. Bursa (Siegesb.) Weber

(Latin, 'purse')

*Bursa bursa-pastoris* (L.) Britton
*Capsella bursa-pastoris* (L.) Medic.
Shepherd's Purse

Winter annual, very common in fields and gardens throughout the entire state, often becoming a bad weed. Naturalized from Europe. April–October

### 7. Neslia Desv.

(Named in honor of J. A. N. de Nesle, a French botanist)

*Neslia paniculata* (L.) Desv. ('tuft')
Ball Mustard

Rarely found in the state. Adventive from Europe. May–September

Specimens examined. — Washtenaw Co. (B. A. Walpole, 1919); Iron Co. (G. S. Butler, 1914).

### 8. Radicula Hill

(Latin, 'root')

| | |
|---|---|
| Plant perennial by creeping or subterranean branches; leaf segments acute, the terminal one lanceolate | |
| Segments of the leaves toothed; style very short, 2 mm. long | 1. *R. sylvestris* |
| Segments of the leaves entire; style slender, 5 mm. long | 2. *R. sinuata* |
| Plants annual or biennials, with fibrous roots; leaf segments obtuse, the terminal one broadly oblong to ovate | |
| Stems glabrous or nearly so; pods linear to linear-oblong | |
| Pedicels shorter than the pods; stems diffusely spreading | 3. *R. obtusa* |
| Pedicels equalling or longer than the pods; stems erect | 4. *R. palustris* |
| Stems hispid-pubescent; pods globose or oval | 5. *R. hispida* |

1. *Radicula sylvestris* (L.) Druce ('of the woods')
Creeping Yellow Water-cress

Wet places, mostly restricted to the southern counties.

Adventive or naturalized from Europe. Summer

Specimens examined. — Wayne Co. (C. F. Wheeler, 1892); Washtenaw Co. (B. A. Walpole, 1919); Alger Co. (C. K. Dodge, 1916); Wayne Co. (C. Billington, 1916); Ingham Co. (B. A. Walpole, 1923); Kent Co. (C. W. Fallass, 1899).

Reported from Wayne Co. (O. A. Farwell, 1904); Roscommon Co. (M. A. C., 1920); Isabella Co. (M. A. C., 1921); Huron Co. (M. A. C., 1923).

2. *Radicula sinuata* (Nutt.) Greene ('curved')

Spreading Yellow Water-cress

Rare in the state. Native. June–September

Specimen examined. — Marquette Co. (Bronson Barlow, 1901).

3. *Radicula obtusa* (Nutt.) Greene ('blunt')

Blunt-leaved Yellow Water-cress

Rare in the state. Native. April-August

Specimens examined. — Keweenaw Co. (O. A. Farwell, 1887); Oceana Co. (C. W. Fallass, 1909).

Reported from Van Buren Co. (M. A. C., 1921).

4. *Radicula palustris* (L.) Moench. ('swampy')

Marsh Water-cress

Throughout the state in swampy places. Naturalized from Europe. May–August

Specimens examined. — Missaukee Co. (H. T. Darlington, 1916); Van Buren Co. (H. S. Pepoon, 1905); Cheboygan Co. (C. F. Wheeler, 1890); Keweenaw Co. (O. A. Farwell, 1888); Calhoun Co. (W. J. Beal, 1898); Genesee Co. (D. Cooley, 1840); Macomb Co. (D. Cooley); Marquette Co. (Bronson Barlow, 1901); Gogebic Co. (H. T. Darlington, 1919); St. Clair Co. (C. K. Dodge, 1896); Washtenaw Co. (B. A. Walpole, 1918); Emmet Co. (J. H. Ehlers, 1923); Livingston Co. (J. H. Ehlers, 1923); Kent Co. (H. M. Bailey, 1891); Allegan Co. (C. H. Kauffman, 1910); Chippewa Co. (C. K. Dodge, 1914); Oakland Co. (Mary Wilkerson, 1895); Shiawassee Co. (C. B. Cook, 1912); Wayne Co. (C. Billington, 1915); Genesee Co. (E. E. Sherff,

1907); Keweenaw Co. (F. E. Wood, 1884); Kent Co. (E. J. Cole, 1901); Kent Co. (C. W. Fallass, 1882); Emmet Co. (C. W. Fallass, 1923).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Manistee Co. (F. P. Daniels, 1902); Hillsdale Co. (M. A. C., 1914); Clinton Co. (M. A. C., 1911); Ottawa Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896); Washtenaw Co. (O. A. Farwell, 1892); Macomb Co. (O. A. Farwell, 1924).

5. *Radicula hispida* (Desv.) Britton ('bristly')

Hispid Yellow Water-cress

In wet places throughout the state. Naturalized from Europe. Summer

Specimens examined. — Cass Co. (H. S. Pepoon, 1904); Osceola Co. (H. T. Darlington, 1916); Montcalm Co. (C. F. Wheeler, 1900); Cheboygan Co. (F. C. Gates, 1911); St. Clair Co. (C. K. Dodge, 1903); Washtenaw Co. (B. A. Walpole, 1919); Emmet Co. (J. H. Ehlers, 1916); Allegan Co. (C. H. Kauffman, 1910); Kent Co. (C. W. Fallass, 1881); Kent Co. (E. J. Cole, 1901); Emmet Co. (C. W. Fallass, 1918).

Reported from Wayne Co. (O. A. Farwell, 1900); Gratiot Co. (C. A. Davis, 1904); Midland Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1886); Dickinson Co. (G. H. Coons, 1909); Keweenaw Co. (O. A. Farwell, 1892); Macomb Co. (O. A. Farwell, 1924).

9. Sisymbrium [Tourn.] L.

(Ancient Greek name)

*Sisymbrium nasturtium-aquaticum* L. ('twisted nose,' 'aquatic')
*Radicula nasturtium* (L.) Britton & Rendle

True Water-cress

Common throughout the state along streams. Naturalized from Europe. April–November

Specimens examined. — Cass Co. (H. S. Pepoon, 1905); Van Buren Co. (H. S. Pepoon, 1906); Crawford Co. (G. H. Hicks,

1888); Kent Co. (E. J. Cole, 1895); Montcalm Co. (C. F. Wheeler, 1900); Ingham Co. (W. J. Beal, 1886); Muskegon Co. (W. J. Beal, 1898); Macomb Co. (D. Cooley); Isabella Co. (C. A. Davis, 1889); Genesee Co. (D. Cooley); Alger Co. (C. F. Wheeler, 1900); Washtenaw Co. (B. A. Walpole, 1918); Kent Co. (C. W. Fallass, 1896); Wayne Co. (C. Billington, 1914); Schoolcraft Co. (A. B. Burgess, 1903); Emmet Co. (C. W. Fallass, 1918).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Ionia Co. (W. J. Beal, 1904); Gratiot Co. (C. A. Davis, 1904); Mackinac Island (C. K. Dodge, 1912); Oakland Co. (O. A. Farwell, 1912); Muskegon Co. (C. D. McLouth, 1896); Monroe Co. (O. A. Farwell, 1910); Macomb Co. (O. A. Farwell, 1897); Wayne Co. (O. A. Farwell, 1897); Washtenaw Co. (O. A. Farwell, 1896).

### 10. Armoracia Gaertn.

(Celtic, 'saline' or 'salty')

*Armoracia armoracia* (L.) Britton

*Radicula Armoracia* (L.) Robinson

Horse-radish

Occasional escape from gardens throughout the state. Adventive from Europe. Summer

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Ingham Co. (W. J. Beal, 1887); Ingham Co. (H. T. Darlington, 1916); St. Clair Co. (C. K. Dodge, 1893); Washtenaw Co. (B. A. Walpole, 1918); Gogebic Co. (H. T. Darlington, 1920); Lapeer Co. (C. K. Dodge, 1916); Kent Co. (C. W. Fallass, 1896); Wayne Co. (C. Billington, 1915); Jackson Co. (E. J. Cole, 1893); Ionia Co. (B. A. Walpole, 1924); Allegan Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1923); Grand Traverse Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1901).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Manistee Co. (F. P.

Daniels, 1900); Oakland Co. (O. A. Farwell, 1912); Emmet Co. (C. W. Fallass, 1918); Ionia Co. (I. W. Stacey).

### 11. Neobeckia Greene

(Named in honor of L. C. Beck, an American botanist)

*Neobeckia aquatica* (Eaton) Britton ('of water')
*Radicula aquatica* (Eaton) Robinson
Lake Water-cress

Rare in the state. Native. Summer

Specimens examined. — Mason Co. (Miss Noppin, 1878); Kent Co. (E. J. Cole, 1901).

Reported from Ingham Co. (W. J. Beal, 1904).

### 12. Lepidium [Tourn.] L.

(Greek, 'a little scale')

| | |
|---|---|
| Stem leaves clasping by an auriculate base | |
| Pods winged; broadly ovate, deeply notched; branches of the inflorescence densely and finely pubescent | 1. *L. campestre* |
| Pods wingless, pointed; branches of the inflorescence glabrous | 2. *L. draba* |
| Stem leaves petioled, sessile, or perfoliate, not clasping | |
| Pods slightly winged above, orbicular or oval | |
| Petals present and broadly spatulate, as long as the calyx; cotyledons accumbent | 3. *L. virginicum* |
| Petals none or minute; cotyledons incumbent | 4. *L. densiflorum* |
| Pods winged all around; oblong or ovate | |
| Lower leaves pinnatifid, upper entire and perfoliate; flowers yellow | 5. *L. perfoliatum* |
| Leaves all pinnatifid, flowers white or pink | 6. *L. sativum* |

1. *Lepidium campestre* (L.) R. Br. ('growing in fields')
Field Cress

In fields and waste places throughout the state. Naturalized from Europe. May–July

Specimens examined. — St. Clair Co. (C. K. Dodge, 1897); Ingham Co. (C. F. Wheeler, 1892); Van Buren Co. (H. S. Pepoon, 1906); Washtenaw Co. (B. A. Walpole, 1919); Cheboygan Co. (J. H. Ehlers, 1922); Emmet Co. (J. H. Ehlers, 1917); Livingston Co. (F. L. Travis, 1916); Clare Co. (W. H. Kennedy,

1917); Ionia Co. (H. B. Webber, 1915); Wayne Co. (I. R. Waterbury, 1915); Alcona Co. (J. F. Barry, 1915); Saginaw Co. (A. R. Wheeler, 1919); Shiawassee Co. (A. F. Goddell, 1914); Tuscola Co. (J. C. Buchringer, 1912); Clinton Co. (I. R. Waterbury, 1912); Muskegon Co. (R. S. Brown, 1919); Allegan Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1923); Wayne Co. (C. Billington, 1915); Genesee Co. (E. E. Sherff, 1909); Ionia Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Lenawee Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1924).

Reported from Bay Co. (G. M. Bradford, 1904); Macomb Co. (W. J. Beal, 1901); Wayne Co. (O. A. Farwell, 1901); Jackson Co. (E. A. Bessey, 1913); Genesee Co. (M. A. C., 1919); Roscommon Co. (M. A. C., 1919); Huron Co. (M. A. C., 1924); Cass Co. (M. A. C., 1924); Leelanau Co. (M. A. C., 1924); Lenawee Co. (M. A. C., 1924); Ottawa Co. (M. A. C., 1924); Hillsdale Co. (M. A. C., 1923); Eaton Co. (M. A. C., 1923); Oakland Co. (O. A. Farwell, 1917); Monroe Co. (O. A. Farwell, 1921).

2. *Lepidium draba* L.

Hoary Cress

Waste grounds; rare. Fugitive from Europe. April–June

Specimen examined. — Washtenaw Co. (B. A. Walpole, 1919).

3. *Lepidium virginicum* L.

Wild Pepper-grass

Throughout the state. Native. May–November

Specimens examined. — Cheboygan Co. (F. C. Gates, 1911); Genesee Co. (D. Cooley, 1871); Ingham Co. (W. J. Beal, 1887); Lenawee Co. (W. J. Beal, 1866); Gratiot Co. (C. A. Davis, 1890); Van Buren Co. (H. S. Pepoon, 1905); Washtenaw Co. (B. A. Walpole, 1918); Kent Co. (W. E. Mulliken, 1895); Washtenaw Co. (E. C. Allmendinger, 1861); St. Clair Co. (C. K. Dodge, 1895); Wayne Co. (Wm. Smith, 1897); St. Joseph Co. (Miss Noppin, 1869); Calhoun Co. (E. C. Phelps, 1915); Allegan Co. (B. A. Walpole, 1924); Wayne Co. (C. Billington, 1915); Schoolcraft Co. (A. B. Burgess, 1903); Mason

Co. (Wilbur Smith, 1911); Jackson Co. (S. H. and D. R. Camp, 1898); Eaton Co. (B. A. Walpole, 1924); Oakland Co. (O. A. Farwell, 1924); Emmet Co. (C. W. Fallass, 1918); Kent Co. (E. J. Cole, 1889).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); Lenawee Co. (F. L. Stearns, 1905); Charity Island (C. K. Dodge, 1910); Mackinac Island (C. K. Dodge, 1912); Isle Royale (W. S. Cooper, 1910); Calhoun Co. (M. A. C., 1915); Gratiot Co. (M. A. C., 1922); Ottawa Co. (M. A. C., 1922); Allegan Co. (M. A. C., 1924); Muskegon Co. (M. A. C., 1924); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896); Dickinson Co. (G. H. Coons, 1909); Washtenaw Co. (O. A. Farwell, 1891); Keweenaw Co. (O. A. Farwell, 1895).

4. *Lepidium densiflorum* Schrad. ('thick-flowered')
*Lepidium intermedium* A. Gray
Wild Pepper-grass
Distributed throughout the state. Naturalized from Europe. May–August

Specimens examined. — Gogebic Co. (H. T. Darlington, 1919); St. Clair Co. (C. K. Dodge, 1895); Washtenaw Co. (L. S. Osband, 1887); Keweenaw Co. (O. A. Farwell, 1889); Marquette Co. (Bronson Barlow, 1901); Alger Co. (C. F. Wheeler, 1900); Otsego Co. (E. A. Bessey, 1912); St. Clair Co. (C. K. Dodge, 1900); Ingham Co. (E. J. Cole, 1895); Bay Co. (C. F. Wheeler, 1901); Kent Co. (H. M. Bailey, 1892); Wayne Co. (C. Billington, 1915); Oakland Co. (C. Billington, 1918); Kent Co. (E. J. Cole, 1894); Ionia Co. (L. H. Bailey, 1878); Eaton Co. (B. A. Walpole, 1924); Muskegon Co. (B. A. Walpole, 1924); Grand Traverse Co. (B. A. Walpole, 1924); Clare Co. (B. A. Walpole, 1924); Lenawee Co. (B. A. Walpole, 1924); Barry Co. (B. A. Walpole, 1924); Jackson Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1918).

Reported from St. Joseph Co. (F. P. Daniels, 1902); Manistee Co. (F. P. Daniels, 1902); Schoolcraft Co. (C. K. Dodge,

1915); Tuscola Co. (C. K. Dodge, 1914); Gratiot Co. (C. A. Davis, 1904); Wayne Co. (O. A. Farwell, 1900); Charity Island (C. K. Dodge, 1910); Cheboygan Co. (F. C. Gates, 1911); Jackson Co. (M. A. C., 1911); Saginaw Co. (M. A. C., 1920); Clinton Co. (M. A. C., 1920); Antrim Co. (E. A. Bessey, 1920); Charlevoix Co. (E. A. Bessey, 1922); Montcalm Co. (E. A. Bessey, 1915); Kalamazoo Co. (M. A. C., 1913); Midland Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Washtenaw Co. (O. A. Farwell, 1892).

5. *Lepidium perfoliatum* L. ('through the leaf')
Perfoliated Mustard
Rarely along railroad tracks. Adventive from Europe. May–July
Specimens examined. — Emmet Co. (C. W. Fallass, 1918); Washtenaw Co. (B. A. Walpole, 1920).

6. *Lepidium sativum* L. ('cultivated')
Garden Cress
Escape from gardens. Native of Europe. May–August
Specimen examined. — St. Clair Co. (C. K. Dodge, 1897).

## 13. Iberis L.

(Named from Iberia, old name of Spain)

Flowers small, 6 mm. wide, raceme elongated; stem usually under 12 inches tall ..... 1. *I. amara*
Flowers large, 8–12 mm. wide, dense clusters; stems usually over 12 inches tall ..... 2. *I. coronaria*

1. *Iberis amara* L. ('bitter')
Candy-tuft
Escape from gardens. Adventive from Europe
Specimen examined. — Ingham Co. (E. A. Bessey, 1924).
Reported from Keweenaw Co. (O. A. Farwell, 1904); Washtenaw Co. (O. A. Farwell, 1892).

2. *Iberis coronaria* D. Don. ('crowning')
Rock Candy-tuft
Rare escape from gardens
Specimen examined. — St. Clair Co. (C. K. Dodge, 1914).

### 14. Hymenophysa C. A. Meyer

*Hymenophysa pubescens* C. A. Meyer

Found along the Michigan Central tracks near Ypsilanti

Specimen examined. — Washtenaw Co. (B. A. Walpole, 1919).

### 15. Thlaspi [Tourn.] L.

(Greek, 'to crush')

*Thlaspi arvense* L. ('of ploughed land')

Field Penny-cress

In cultivated fields throughout the Southern Peninsula. Naturalized from Europe. June–August

Specimens examined. — St. Clair Co. (C. K. Dodge, 1904); Ingham Co. (W. J. Beal, 1887); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (Lewis Foote, 1863); Marquette Co. (C. A. Davis, 1906); Hillsdale Co. (N. S. Fields, 1915); Alcona Co. (G. A. McClatchy, 1915); Eaton Co. (B. A. Walpole, 1922); Wayne Co. (C. Billington, 1914); Kent Co. (E. J. Cole, 1895); Emmet Co. (C. W. Fallass, 1912).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Tuscola Co. (C. K. Dodge, 1914); Monroe Co. (C. A. Davis, 1904); Manistee Co. (F. P. Daniels, 1900); Isle Royale (W. S. Cooper, 1910); Gladwin Co. (M. A. C., 1917); Eaton Co. (M. A. C., 1916); Cass Co. (M. A. C., 1919); Lapeer Co. (M. A. C., 1917); Huron Co. (M. A. C., 1920); Bay Co. (M. A. C., 1920); Gratiot Co. (M. A. C., 1922); Newaygo Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Wayne Co. (O. A. Farwell, 1908); Monroe Co. (O. A. Farwell, 1921).

### 16. Sophia Adans.

(Name due to reputed medicinal value)

| | |
|---|---|
| Pods narrowly linear, curved upwards | 1. *S. sophia* |
| Pods linear-oblong, straight | |
| Pedicels equalling or longer than silique; pods compressed; seeds distinctly in 2 rows in the cell | 2. *S. pinnata* |
| Pedicels shorter than the silique; pods swollen; seeds distinctly 1-rowed in the cell | 3. *S. incisa* |

1. *Sophia sophia* (L.) Britton
   *Sisymbrium sophia* L.
   Flix-weed; Herb Sophia
   Rare in the northern part of the state. Naturalized from Europe. June–August

Reported from Keweenaw Co. (O. A. Farwell, 1904); Emmet Co. (C. W. Fallass, 1918).

2. *Sophia pinnata* (Walt.) Howell ('feathered')
   *Sisymbrium canescens* Nutt.
   Tansy Mustard
   Apparently rare. Native. May–July

Specimens examined. — Emmet Co. (C. F. Wheeler, 1897); Kent Co. (E. J. Cole, 1897); Thunder Bay Island (C. F. Wheeler, 1908); Emmet Co. (C. W. Fallass, 1918).

Reported from Wayne Co. (O. A. Farwell, 1900); Barry Co. (L. H. Bailey, 1904); Muskegon Co. (C. D. McLouth, 1896).

3. *Sophia incisa* (Engelm.) Greene ('cut into')
   *Sisymbrium incisum* Engelm.
   Western Tansy Mustard
   Native. May–August

Specimen examined. — Cheboygan Co. (J. H. Ehlers, 1920).

## 17. Cheirinia Link.

(Greek, 'similar to Cheiri')

| | |
|---|---|
| Petals less than 1 cm. long | |
| Pedicels slender, spreading; petals 4–5 mm. long | 1. *C. cheiranthoides* |
| Pedicels stout and short; petals 6–10 mm. long | |
| Perennials; pods ascending | 2. *C. inconspicua* |
| Annuals; pods spreading | 3. *C. repanda* |
| Petals more than 1 cm. long | 4. *C. aspera* |

1. *Cheirinia cheiranthoides* (L.) Link. ('like Cheirinia')
   *Erysimum cheiranthoides* L.
   Worm-seed Mustard
   Found throughout the state in waste places. Adventive from Europe. June–August

Specimens examined. — Muskegon Co. (C. D. McLouth,

1901); St. Clair Co. (C. K. Dodge, 1896); Ingham Co. (H. T. Darlington, 1916); Alger Co. (C. F. Wheeler, 1900); Marquette Co. (Bronson Barlow, 1901); Houghton Co. (O. A. Farwell, 1887); Otsego Co. (E. A. Bessey, 1912); Washtenaw Co. (D. R. Sharp, 1867); Cheboygan Co. (J. H. Ehlers, 1917); Keweenaw Co. (O. A. Farwell, 1884); Shiawassee Co. (L. Grant, 1915); Ionia Co. (H. B. Webber, 1915); Lapeer Co. (Martha MacArthur, 1914); Wayne Co. (C. Billington, 1915); Oakland Co. (C. Billington, 1896); Emmet Co. (E. J. Cole, 1894); Kent Co. (E. J. Cole, 1896); Eaton Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1924); Ionia Co. (B. A. Walpole, 1924).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); Manistee Co. (F. P. Daniels, 1900); Gratiot Co. (C. A. Davis, 1904); Crawford Co. (G. H. Hicks, 1904); Charity Island (C. K. Dodge, 1910); Mackinac Island (C. K. Dodge, 1912); Isle Royale (W. S. Cooper, 1910); Gogebic Co. (H. T. Darlington, 1920); Saginaw Co. (M. A. C., 1916); Clinton Co. (M. A. C., 1920); Charlevoix Co. (M. A. C., 1922); Mackinac Co. (M. A. C., 1920); Monroe Co. (M. A. C., 1919); Allegan Co. (M. A. C., 1920); Muskegon Co. (M. A. C., 1920); Genesee Co. (M. A. C., 1924); Midland Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1899); Emmet Co. (C. W. Fallass, 1918).

2. *Cheirinia repanda* (L.) Link. ('bent backwards')
*Erysimum repandum* L.
Rarely found in the state. Adventive from Europe. May–July

Specimens examined. — St. Clair Co. (C. K. Dodge, 1900); St. Clair Co. (C. Billington, 1915).

Reported from Monroe Co. (O. A. Farwell, 1921).

3. *Cheirinia inconspicua* (S. Wats.) Britton ('inconspicuous')
*Erysimum parviflorum* Nutt.
Small-flowered Prairie-rocket
A perennial of dry soil; occasionally adventive from the west. July–August

Specimen examined. — St. Clair Co. (C. K. Dodge, 1900).

Reported from Keweenaw Co. (O. A. Farwell, 1904); Isle Royale (W. S. Cooper, 1910); Wayne Co. (O. A. Farwell, 1922).

4. *Cheirinia aspera* (DC.) Britton ('rough')
*Erysimum asperum* DC.
Western Wall-flower

Specimen examined. — Kent Co. (E. J. Cole, 1901).

### 18. Erysimum [Tourn.]

(Greek name for some garden plant)

*Erysimum officiale* L. (official)
*Sisymbrium officinale* (L.) Scop.
Hedge Mustard

Distributed throughout the state. Annual or winter annual. Naturalized from Europe. May–November

Specimens examined. — Ingham Co. (W. J. Beal, 1872); Van Buren Co. (H. S. Pepoon, 1905); Macomb Co. (D. Cooley, 1843); St. Clair Co. (C. K. Dodge, 1896); Washtenaw Co. (B. A. Walpole, 1919); Gogebic Co. (H. T. Darlington, 1919); Wayne Co. (C. Billington, 1918); Oakland Co. (C. Billington, 1918); Eaton Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1924); Lenawee Co. (B. A. Walpole, 1924); Muskegon Co. (B. A. Walpole, 1924); Allegan Co. (B. A. Walpole, 1924); Jackson Co. (B. A. Walpole, 1924); Barry Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1893).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Manistee Co. (F. P. Daniels, 1900); Charity Island (C. K. Dodge, 1910); Mackinac Island (C. K. Dodge, 1912); Oakland Co. (O. A. Farwell, 1912); Isabella Co. (E. A. Bessey, 1912); Antrim Co. (E. A. Bessey, 1912); Jackson Co. (E. A. Bessey, 1915); Montcalm Co. (M. A. C., 1915); Genesee Co. (M. A. C., 1920); Charlevoix Co. (M. A. C., 1920); Ottawa Co. (M. A. C., 1922); Allegan Co. (M. A. C., 1924); Leelanaw Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Muskegon Co.

(C. D. McLouth, 1896); Emmet Co. (C. W. Fallass, 1896); Keweenaw Co. (O. A. Farwell, 1890); Washtenaw Co. (O. A. Farwell, 1891).

### 19. Norta Adans.

Pods stiff and divergent; short thick pedicels..... 1. *N. altissima*
Pods soft and ascending; slender pedicels..... 2. *N. irio*

1. *Norta altissima* (L.) Britton ('very tall')
*Sisymbrium altissimum* L.
Tall Mustard
Scattered throughout the state. Naturalized from Europe. Summer

Specimens examined. — St. Clair Co. (C. K. Dodge, 1902); Alger Co. (C. F. Wheeler, 1900); Eaton Co. (H. L. Clark, 1900); Van Buren Co. (C. F. Wheeler, 1896); Otsego Co. (E. A. Bessey, 1912); Missaukee Co. (H. T. Darlington, 1916); Washtenaw Co. (B. A. Walpole, 1918); Cheboygan Co. (J. H. Ehlers, 1923); Mackinac Co. (C. K, Dodge, 1914); Cass Co. (H. S. Pepoon, 1907); Antrim Co. (B. J. Rauch, 1914); Wayne Co. (C. Billington, 1914); Midland Co. (R. R. Dreisback, 1914); Emmet Co. (F. C. Gates, 1917); Menominee Co. (C. F. Milspaugh, 1913); Clinton Co. (B. A. Walpole, 1924); Clare Co. (B. A. Walpole, 1924); Roscommon Co. (B. A. Walpole, 1924); Wexford Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1918); Ingham Co. (B. A. Walpole, 1924); Lenawee Co. (B. A. Walpole, 1924); Allegan Co. (B. A. Walpole, 1924); Muskegon Co. (B. A. Walpole, 1924); Barry Co. (B. A. Walpole, 1924).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Berrien Co. (C. F. Wheeler, 1896); Wayne Co. (O. A. Farwell, 1904); Cheboygan Co. (F. C. Gates, 1911); Oakland Co. (O. A. Farwell, 1914); Isle Royale (W. S. Cooper, 1910); Gogebic Co. (H. T. Darlington, 1919); Lenawee Co. (E. A. Bessey, 1916); Ogemaw Co. (M. A. C., 1919); Tuscola Co. (M. A. C., 1916); Montcalm Co. (E. A. Bessey, 1915); Lapeer Co. (E. A. Bessey, 1917); Sanilac Co. (M. A. C., 1917); Gratiot Co. (M. A. C., 1919); Montmorency Co. (M. A. C., 1919);

Oakland Co. (M. A. C., 1920); Huron Co. (M. A. C., 1920); Oceana Co. (M. A. C., 1920); Alcona Co. (E. A. Bessey, 1920); Jackson Co. (M. A. C., 1922); Mecosta Co. (M. A. C., 1922); Livingston Co. (M. A. C., 1924); Genesee Co. (M. A. C., 1924).

2. *Norta irio* (L.) Britton
*Sisymbrium irio* L.
Sporadic in waste grounds. Fugitive from Europe. Summer
Specimen examined. — Kent Co. (E. J. Cole, 1900).

### 20. Conringia (Heist.) Adans.

(Named in honor of Hermann Conring)

*Conringia orientalis* (L.) Dumort. ('oriental')
Hare's-ear Mustard
Occasionally found in waste places and along railroads. Adventive from the northwest. May–August
Specimens examined. — Keweenaw C. (O. A. Farwell, 1890); Wastenaw Co. (B. A. Walpole, 1920); St. Clair Co. (C. K. Dodge, 1917); Wayne Co. (C. Billington, 1915).
Reported from Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1917); Oakland Co. (O. A. Farwell, 1917).

### 21. Hesperis [Tourn.] L.

(From a Greek word meaning evening, a time when the flowers are fragrant)

*Hesperis matronalis* L. ('pertaining to mother')
Dame's Rocket
Found only in the southern part of the state. Native of Europe. May–August
Specimens examined. — Macomb Co. (D. Cooley, 1842); Muskegon Co. (C. D. McLouth, 1900); Cass Co. (C. F. Wheeler, 1890); Washtenaw Co. (B. A. Walpole, 1918); Ingham Co. (B. A. Walpole, 1922); Ionia Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1923); Washtenaw Co. (M. W. Harrington, 1870); Oakland Co. (M. J. Whiting, 1868); St. Clair Co. (C. K.

Dodge, 1913); Allegan Co. (B. A. Walpole, 1924); Kent Co. (C. W. Fallass, 1896).

Reported from Wayne Co. (O. A. Farwell, 1900); Berrien Co. (C. F. Wheeler, 1904); Keweenaw Co. (O. A. Farwell, 1904); Ionia Co. (I. W. Stacey); Oakland Co. (O. A. Farwell, 1924).

### 22. Arabidopsis (DC.) Schur.

('resembling Arabis')

| | |
|---|---|
| Annual; pods linear, slightly 4-sided, pedicels spreading | 1. *A. thaliana* |
| Perennial; pods cylindric, pedicels erect | 2. *A. novae-angliae* |

1. *Arabidopsis thaliana* (L.) Br.
   *Sisymbrium thalianum* (L.) J. Gay
   Mouse-ear Cress
   Found in the southwestern part of the state. Naturalized from Europe. April–May

Specimens examined. — Cass Co. (H. S. Pepoon, 1906); Berrien Co. (Mrs. Ralph Ballard, 1901).

2. *Arabidopsis novae-angliae* (Rydb.) Britton (New England)
   *Braya humilis* (C. A. Mev.) Robinson
   Northern Rock Cress
   Found occasionally in northern part of the state. Native. July

Reported from St. Clair Co. (C. K. Dodge, 1913); Isle Royale (Gillman, 1904); Keweenaw Co. (O. A. Farwell, 1904); Mackinac Co. (G. M. Hicks, 1904); Macomb Co. (W. J. Beal, 1904); Mackinac Island (C. K. Dodge, 1912).

### 23. Barbarea R. Br.

(Named from St. Barbara)

| | |
|---|---|
| Pods obtusely 4-angled, slender pedicelled; leaf segments 1–4 pairs | |
| Pods divergent or ascending | 1. *B. barbarea* |
| Pods erect, appressed | 2. *B. stricta* |
| Pods sharply 4-angled, stout pedicelled; leaf segments 4–8 pairs | 3. *B. verna* |

1. *Barbarea barbarea* (L.) MacM.
*Barbarea vulgaris* R. Br.
Yellow Rocket
Found throughout the state. Naturalized from Europe.
April–June

Specimens examined. — Muskegon Co. (C. D. McLouth, 1899); Van Buren Co. (H. S. Pepoon, 1906); St. Clair Co. (C. K. Dodge, 1893); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (C. K. Dodge, 1913); Benzie Co. (A. C. Demerly, 1915); Livingston Co. (C. N. Frolin, 1915); Jackson Co. (B. L. Smith, 1915); Saginaw Co. (G. H. Bennett, 1915); Ingham Co. (B. A. Walpole, 1921); Oakland Co. (C. Billington, 1916); Grand Traverse Co. (Agnes Maher, 1911); Eaton Co. (B. A. Walpole, 1922); Washtenaw Co. (C. Billington, 1919); Wayne Co. (C. Billington, 1914); Muskegon Co. (L. M. Umback, 1898); Grand Traverse Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1894); Emmet Co. (C. W. Fallass, 1918).

Reported from Chippewa Co. (C. K. Dodge, 1914); Macomb Co. (W. J. Beal, 1904); Gratiot Co. (C. A. Davis, 1904); Clinton Co. (C. F. Wheeler, 1904); Bay Co. (G. M. Bradford, 1904); Oakland Co. (O. A. Farwell, 1912); Isle Royale (W. S. Cooper, 1910); Gogebic Co. (H. T. Darlington, 1920); Lapeer Co. (M. A. C., 1917); Sanilac Co. (M. A. C., 1916); Ionia Co. (M. A. C., 1915); Manistee Co. (M. A. C., 1916); Barry Co. (M. A. C., 1916); Benzie Co. (M. A. C., 1915); Kalmazoo Co. (M. A. C., 1914); Lenawee Co. (M. A. C., 1913); Calhoun Co. (M. A. C., 1918); Genesee Co. (M. A. C., 1911); Clinton Co. (M. A. C., 1911); Tuscola Co. (M. A. C., 1920); Hillsdale Co. (M. A. C., 1921); Jackson Co. (M. A. C., 1922); Cass Co. (M. A. C., 1922); Shiawassee Co. (M. A. C., 1922); Branch Co. (M. A. C., 1924); Midland Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Houghton Co. (O. A. Farwell, 1915); Keweenaw Co. (O. A. Farwell, 1884).

2. *Barbarea stricta* Andrz. ('erect')
Erect-fruited Winter Cress
Frequently found with the preceding species. Naturalized from Europe. April–June

Specimens examined. — St. Clair Co. (C. K. Dodge, 1900); Wayne Co. (W. S. Cooper, 1902); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (B. Gladowitz, 1915); Emmet Co. (C. W. Fallass, 1920); Oakland Co. (C. Billington, 1918); Ingham Co. (B. A. Walpole, 1921); Clinton Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1900).

Reported from Wayne Co. (O. A. Farwell, 1900); Keweenaw Co. (O. A. Farwell, 1898).

3. *Barbarea verna* (Mill.) Aschers. ('of spring')
Early Winter Belle Isle Cress
Rarely found in the state. Adventive from Europe.
April–June

Reported from St. Clair Co. (C. K. Dodge, 1904); Oakland Co. (O. A. Farwell, 1917); Monroe Co. (O. A. Farwell, 1921)

## 24. Arabis L.

(Named from Arabia)

Stem leaves cordate or sagittate at the base and sessile, more or less clasping
- Seeds in 2 rows in each cell of the pod
  - Calyx pubescent; the pods reflexed..... 1. *A. Holboellii*
  - Calyx glabrous; pods spreading or erect
    - Basal leaves densely pubescent with three-pointed hairs; pods spreading... 2. *A. brachycarpa*
    - Basal leaves smooth or nearly so; pods erect..... 3. *A. drummondii*
- Seeds in 1 row in each cell of the pod..... 4. *A. laevigata*

Stem leaves sessile or somewhat peticelled, but not clasping. Seeds in 1 row in each cell of the pod
- Basal leaves pinnatifid; pods ascending
  - Petals much longer than calyx..... 5. *A. lyrata*
- Basal leaves merely dentate or lyrate;
  - Petals scarcely exceeding the calyx
    - Seeds minute, oblong, and wingless
      - Plants pubescent; flowers greenish white..... 6. *A. dentata*
      - Plants glabrous; flowers yellowish white..... 7. *A. glabra*
    - Seeds larger, winged or winged-margined
      - Pods nearly erect; pedicels glabrous..... 8. *A. hirsuta*
      - Pods recurved-spreading; pedicels hairy..... 9. *A. canadensis*

1. *Arabis holboellii* Hornem. (named for Holboel)
Holboel's Rock-cress
Found in the northern part of the state. Native. Summer

Specimens examined. — Alpena Co. (C. F. Wheeler, 1897); Alpena Co. (C. K. Dodge, 1907); Emmet Co. (J. H. Ehlers, 1917); Delta Co. (C. K. Dodge, 1893); Cheboygan Co. (C. K. Dodge, 1917).

Reported from Mackinac Island (C. K. Dodge, 1913).

2. *Arabis brachycarpa* (T. & C.) Britton ('short carpels')
Purple Rock-cress
Found mostly in the northern part of the state. Native. June–July

Specimens examined. — Keweenaw Co. (O. A. Farwell, 1888); Alpena Co. (C. A. Davis, 1891); Mackinac Island (G. H. Hicks, 1889); Cheboygan Co. (J. H. Ehlers, 1920); Marquette Co. (C. K. Dodge, 1916); Montcalm Co. (C. W. Fallass, 1881); Muskegon Co. (C. W. Fallass, 1899); Emmet Co. (M. F. and F. C. Gates, 1917); Cheboygan Co. (M. F. and F. C. Gates, 1917).

Reported from Kent Co. (E. J. Cole, 1901); Clinton Co. (C. F. Wheeler, 1904); Isle Royale (W. S. Cooper, 1910); Gogebic Co. (H. T. Darlington, 1920); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1897); Emmet Co. (C. W. Fallass, 1918).

3. *Arabis drummondii* A. Gray (named for Drummond)
Drummond's Rock-cress
Found in the west-central and northern part of the state. Native. May–August

Specimens examined. — St. Clair Co. (C. K. Dodge, 1897); St. Joseph Co. (C. F. Wheeler, 1890); Oscoda Co. (C. F. Wheeler, 1888); Alpena Co. (C. F. Wheeler, 1895); Muskegon Co. (C. F. Wheeler, 1900); Cheboygan Co. (J. H. Ehlers, 1917); Berrien Co. (G. L. Ames, 1868); Allegan Co. (L. H. Pennington, 1910); Kent Co. (A. J. Pieters, 1893); Allegan Co. (C. H. Kauffman, 1910); Alcona Co. (C. K. Dodge, 1912); Keweenaw

Co. (O. A. Farwell, 1884); Kent Co. (C. W. Fallass, 1897); Mackinac Island (E. J. Cole, 1898); Thunder Bay Island (E. J. Cole, 1895); Kent Co. (E. J. Cole, 1893); Allegan Co. (W. E. Mulliken, 1897); Mackinac Island (G. H. Hicks, 1889); Mackinac Island (T. E. Boyce, 1881).

Reported from Charity Island (C. K. Dodge, 1910); Isle Royale (W. S. Cooper, 1910); St. Joseph Co. (M. A. C., 1916).

4. *Arabis laevigata* (Muhl.) Poir. ('slippery' or 'smooth')
Smooth Rock-cress
Throughout the state. Native. April–June

Specimens examined. — Macomb Co. (D. Cooley, 1843); St. Clair Co. (C. K. Dodge, 1892); Ingham Co. (H. T. Darlington, 1916); Van Buren Co. (H. S. Pepoon, 1906); Gratiot Co. (C. A. Davis, 1891); Washtenaw Co. (B. A. Walpole, 1924); Washtenaw Co. (A. J. Pieters, 1892); Menominee Co. (C. K. Dodge, 1905); Eaton Co. (C. F. Wheeler, 1890); Lenawee Co. (C. Billington, 1918); Kent Co. (W. E. Mulliken, 1897); Ingham Co. (H. C. Skeels, 1895); Ottawa Co. (W. E. Mulliken, 1895); Allegan Co. (B. A. Walpole, 1924); Grand Traverse Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1897).

Reported from Tuscola Co. (C. A. Davis, 1908); Manistee Co. (F. P. Daniels, 1900); Charity Island (C. K. Dodge, 1910); Oakland Co. (O. A. Farwell, 1912); Allegan Co. (M. A. C., 1919); Muskegon Co. (N. C. Gage, 1919); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896); Keweenaw Co. (O. A. Farwell, 1884).

5. *Arabis lyrata* L. ('lute' or 'lyre')
Lyre-leaved Rock-cress
Distributed throughout the state. Native. April–September

Specimens examined. — Isle Royale (O. A. Farwell, 1886); Muskegon Co. (W. J. Beal, 1898); Huron Co. (C. A. Davis, 1896); St. Clair Co. (C. K. Dodge, 1900); Grand Traverse Co. (C. F. Wheeler, 1898); Alpena Co. (C. F. Wheeler, 1895); Shiawassee Co. (C. F. Wheeler, 1890); Macomb Co. (D. Cooley,

1842); Benzie Co. (L. H. Bailey, 1888); Clinton Co. (C. F. Wheeler, 1889); Genesee Co. (D. Clark, 1888); Muskegon Co. (C. F. Wheeler, 1900); Washtenaw Co. (B. A. Walpole, 1919); Emmet Co. (J. H. Ehlers, 1922); Berrien Co. (G. L. Ames, 1867); Kent Co. (H. M. Bailey, 1892); Alger Co. (C. K. Dodge, 1916); Schoolcraft Co. (C. K. Dodge, 1916); Oakland Co. (C. Billington, 1916); St. Clair Co. (C. Billington, 1915); Kent Co. (C. W. Fallass, 1896); Kent Co. (G. D. Sones, 1897); Emmet Co. (M. F. and F. C. Gates, 1917); Ionia Co. (B. A. Walpole, 1921); Ingham Co. (B. A. Walpole, 1921); Muskegon Co. (B. A. Walpole, 1924); Clare Co. (B. A. Walpole, 1924); Roscommon Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1899); Kent Co. (D. J. Cole, 1901).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Manistee Co. (F. P. Daniels, 1900); Charity Island (C. K. Dodge, 1910); Isle Royale (W. S. Cooper, 1910); Newaygo Co. (E. A. Bessey, 1920); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896); Keweenaw Co. (O. A. Farwell, 1884); Oakland Co. (O. A. Farwell, 1896); Macomb Co. (O. A. Farwell, 1916).

6. *Arabis dentata* T. & G. ('toothed')
Toothed Rock-cress

Rarely found in the state. Native. April–June

Specimens examined. — Kent Co. (C. F. Wheeler, 1895); St. Clair Co. (C. K. Dodge, 1910); Kent Co. (C. W. Fallass, 1897); Kent Co. (E. J. Cole, 1895).

Reported from Ingham Co. (W. J. Beal, 1904).

7. *Arabis glabra* (L.) Bernh. ('smooth')
Tower Mustard

Distributed throughout the state. Probably indigenous. May–August

Specimens examined. — Ingham Co. (C. F. Wheeler, 1897); Gogebic Co. (H. T. Darlington, 1919); St. Clair Co. (C. K. Dodge, 1897); Cheboygan Co. (F. C. Gates, 1911); Ingham Co. (W. J. Beal, 1887); Montmorency Co. (C. F. Wheeler, 1895);

Muskegon Co. (C. D. McLouth, 1899); Washtenaw Co. (B. A. Walpole, 1919); Allegan Co. (C. H. Kauffman, 1910); Bay Co. (C. K. Dodge, 1912); Osceola Co. (E. Gustafson, 1915); Wayne Co. (C. Billington, 1915); Emmet Co. (Wilbur Smith, 1911); Eaton Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1894).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Kent Co. (E. J. Cole, 1901); Schoolcraft Co. (C. K. Dodge, 1915); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); Gratiot Co. (C. A. Davis, 1904); Ogemaw Co. (E. A. Bessey, 1922); Keweenaw Co. (O. A. Farwell, 1895); Newaygo Co. (O. A. Farwell, 1921); Eaton Co. (O. A. Farwell, 1923); Monroe Co. (O. A. Farwell, 1918).

8. *Arabis hirsuta* (L.) Scop. ('hairy')

Hairy Rock-cress

Locally found throughout the state. Probably native.

May–September

Specimens examined. — Ingham Co. (C. F. Wheeler, 1895); Thunder Bay Island (C. F. Wheeler, 1895); Clinton Co. (D. F. Wheeler, 1890); Keweenaw Co. (O. A. Farwell); Ingham Co. (W. J. Beal, 1866); Emmet Co. (C. F. Wheeler, 1890); Van Buren Co. (H. S. Pepoon, 1905); Ingham Co. (E. J. Cole, 1895); Ingham Co. (W. J. Beal, 1887); Washtenaw Co. (B. A. Walpole, 1918); Kent Co. (C. W. Fallass, 1899); Oakland Co. (C. Billington, 1917); Kent Co. (H. C. Skeels, 1895); Ingham Co. (W. E. Mulliken, 1895); Van Buren Co. (L. H. Bailey, 1880); Kent Co. (E. J. Cole, 1895).

Reported from Bay Co. (G. M. Bradford, 1904); Mackinac Island (C. K. Dodge, 1912); Isle Royale (W. S. Cooper, 1910); Ionia Co. (I. W. Stacey); Emmet Co. (C. W. Fallass, 1918); Oakland Co. (O. A. Farwell, 1913); Mackinac Co. (O. A. Farwell, 1895).

9. *Arabis canadensis* L. ('of Canada')

Sickle-pod

Found throughout the southern half of the state. Native.

June–August

Specimens examined. — Genesee Co. (D. Clark, 1872); Newaygo Co. (E. A. Bessey, 1916); St. Clair Co. (C. K. Dodge, 1903); Macomb Co. (D. Cooley, 1837); Van Buren Co. (H. S. Pepoon, 1905); Washtenaw Co. (B. A. Walpole, 1919); Kent Co. (H. M. Bailey, 1892); Kent Co. (C. W. Fallass, 1896); Wayne Co. (C. Billington, 1915); Lenawee Co. (C. Billington, 1914); Ingham Co. (G. D. Sones, 1898); Kent Co. (W. E. Mulliken, 1896); Muskegon Co. (B. A. Walpole, 1924); Ionia Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1901).

Reported from Wayne Co. (O. A. Farwell, 1900); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1897); Livingston Co. (O. A. Farwell, 1905).

### 25. Cardamine [Tourn.] L.

(Greek, 'heart-strengthening')

Flowers purple
- Leaves pinnately divided ..... 1. *C. pratensis*
- Leaves not pinnately divided ..... 2. *C. douglassii*

Flowers white
- Having tubers or tuberous-rooted ..... 3. *C. bulbosa*
- Having no tubers or tuberous roots
  - Hirsute pubescence ..... 4. *C. hirsuta*
  - Glabrous or nearly so
    - Plants of dry rocky places; flowers 4–5 mm. wide ..... 5. *C. parviflora*
    - Plants of wet places; flowers 2–3 mm. wide ..... 6. *C. pennsylvanica*

1. *Cardamine pratensis* L. ('of the meadow')
   Meadow Bitter-cress

   Found in wet places in the Southern Peninsula. Apparently native. April–May

Specimens examined. — Ingham Co. (W. J. Beal, 1871); Hillsdale Co. (D. A. Pelton, 1885); Alcona Co. (W. J. Beal, 1888); Clinton Co. (C. F. Wheeler, 1890); Macomb Co. (D. Cooley, 1845); Washtenaw Co. (B. A. Walpole, 1918); Cheboygan Co. (J. H. Ehlers, 1923); Washtenaw Co. (E. C. Allmendinger, 1862); Livingston Co. (J. H. Ehlers, 1920); St. Clair Co. (C. K. Dodge, 1896); Kent Co. (C. W. Fallass, 1895); St.

Clair Co. (C. Billington, 1915); Oakland Co. (C. Billington, 1914); Genesee Co. (H. N. Patterson, 1900); Kalamazoo Co. (G. H. Tuthill, 1873); Jackson Co. (S. H. and D. R. Camp, 1897); Kent Co. (E. J. Cole, 1895); Emmet Co. (C. W. Fallass, 1918).

Reported from Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); St. Joseph Co. (F. P. Daniels, 1902); Oakland Co. (O. A. Farwell, 1912); Calhoun Co. (M. A. C., 1922); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896).

2. *Cardamine douglassii* (Torr.) Britton (named for Douglass) Purple Cress

Throughout the Southern Peninsula. Native. April–May

Specimens examined. — St. Clair Co. (C. K. Dodge, 1897); Cass Co. (H. S. Pepoon, 1905); Ingham Co. (W. J. Beal, 1865); Kent Co. (E. J. Cole, 1895); Washtenaw Co. (B. A. Walpole, 1918); Washtenaw Co. (E. C. Allmendinger, 1867); Emmet Co. (C. W. Fallass, 1896); Wayne Co. (C. Billington, 1914); Kent Co. (G. D. Sones, 1889); Jackson Co. (S. H. and D. R. Camp, 1897); Eaton Co. (B. A. Walpole, 1924); Ionia Co. (B. A. Walpole, 1924); Barry Co. (B. A. Walpole, 1924); Clinton Co. (B. A. Walpole, 1924).

Reported from Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Ionia Co. (I. W. Stacey); Washtenaw Co. (O. A. Farwell, 1891); Oakland Co. (O. A. Farwell, 1914).

3. *Cardamine bulbosa* (Schreb.) B. S. P. ('bulbous' or 'ball-like') Bulbous Cress

Throughout the Southern Peninsula. Native. April–June

Specimens examined. — St. Clair Co. (C. K. Dodge, 1895); Ingham Co. (W. J. Beal, 1887); Kent Co. (E. J. Cole, 1895); Muskegon Co. (W. J. Beal, 1898); Washtenaw Co. (B. A. Walpole, 1918); Wayne Co. (W. J. Gillespie, 1897); Wayne Co. (C. Billington, 1914); Oakland Co. (C. Billington, 1914); Emmet Co. (C. W. Fallass, 1918).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Tus-

cola Co. (C. K. Dodge, 1908); St. Joseph Co. (F. D. Daniels, 1902); Manistee Co. (F. P. Daniels, 1900); Oakland Co. (O. A. Farwell, 1912); Sanilac Co. (M. A. C., 1923); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1897); Washtenaw Co. (O. A. Farwell, 1891); Wayne Co. (O. A. Farwell, 1893); Ingham Co. (O. A. Farwell, 1905); Monroe Co. (O. A. Farwell, 1920).

4. *Cardamine hirsuta* L. ('hairy')
Hairy Bitter-cress
Infrequently found in the state. Probably native. March–May

Specimens examined. — Keweenaw Co. (O. A. Farwell, 1884); Washtenaw Co. (Avis Gray Chapel, 1896); Montcalm Co. (C. W. Fallass, 1881); Kent Co. (C. W. Fallass, 1897); St. Clair Co. (C. K. Dodge, 1895); Kent Co. (E. J. Cole, 1901).

Reported from Wayne Co. (O. A. Farwell, 1900); Berrien Co. (C. F. Wheeler, 1904); Cheboygan Co. (W. J. Beal, 1904); Gratiot Co. (C. A. Davis, 1904); Ingham Co. (W. J. Beal, 1904); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896).

5. *Cardamine parviflora* L. ('small flowered')
Small-flowered Bitter-cress
Rarely found in the state. Probably native. April–May

Specimen examined. — Marquette Co. (C. K. Dodge, 1917).

Reported from Kent Co. (E. J. Cole, 1901); Berrien Co. (C. F. Wheeler, 1904); Cheboygan Co. (W. J. Beal, 1904); Keweenaw Co. (O. A. Farwell, 1904); St. Clair Co. (I. W. Stacey); Gogebic Co. (H. T. Darlington, 1920).

6. *Cardamine pennsylvanica* Muhl. ('of Pennsylvania')
Pennsylvania Bitter-cress
Found throughout the state. Native. April–June

Specimens examined. — St. Clair Co. (C. K. Dodge, 1895); Marquette Co. (Bronson Barlow, 1901); Ingham Co. (C. F. Wheeler, 1900); Van Buren Co. (H. S. Pepoon, 1906); Alger Co. (C. F. Wheeler, 1900); Keweenaw Co. (O. A. Farwell, 1884);

Calhoun Co. (C. W. Fallass, 1910); Wayne Co. (C. Billington, 1915); Eaton Co. (B. A. Walpole, 1924); Washtenaw Co. (B. A. Walpole, 1919); Kent Co. (E. J. Cole, 1895); Emmet Co. (C. W. Fallass, 1918).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Bay Co. (G. M. Bradford, 1904); Cheboygan Co. (F. C. Gates, 1911); Isle Royale (W. S. Cooper, 1910); Gogebic Co. (H. T. Darlington, 1920); Oakland Co. (O. A. Farwell, 1923).

## 26. Dentaria [Tourn.] L.

(Latin, 'toothed')

Stem glabrous
- Rootstocks continuous, prominently toothed; stem leaves 2, opposite or close together ..... 1. *D. diphylla*
- Rootstocks interrupted by distinct constrictions; stem leaves 2–5, alternate ..... 2. *D. maxima*

Stems pubescent, at least above; rootstocks readily separable, obtusely toothed ..... 3. *D. laciniata*

1. *Dentaria diphylla* Michx. ('two-leaved')

Two-leaved Toothwort

Probably found throughout the state. Native. May

Specimens examined. — St. Clair Co. (C. K. Dodge, 1895); Ingham Co. (G. H. Hicks, 1893); Macomb Co. (D. Cooley, 1839); Ingham Co. (W. J. Beal, 1864); Ingham Co. (F. J. Sleeper, 1868); Marquette Co. (Bronson Barlow, 1901); Keweenaw Co. (O. A. Farwell, 1888); Cass Co. (H. S. Pepoon, 1906); Gratiot Co. (C. A. Davis, 1888); Washtenaw Co. (B. A. Walpole, 1918); Kent Co. (H. M. Bailey, 1891); Oakland Co. (O. A. Farwell, 1897); Oakland Co. (C. Billington, 1915); Gratiot Co. (C. A. Davis, 1895); Kent Co. (E. J. Cole, 1892); Emmet Co. (C. W. Fallass, 1918).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Tuscola Co. (C. K. Dodge, 1908); Manistee Co. (F. P. Daniels, 1900); Mackinac Island (C. K. Dodge, 1912); Gogebic Co. (H. T. Darlington, 1920); Ionia Co. (I. W. Stacey).

2. *Dentaria maxima* Nutt. ('largest')
Large Toothwort
Rarely found in the state. Native. May
Specimens examined. — St. Clair Co. (C. K. Dodge, 1898); Washtenaw Co. (Lewis Foote, 1863).

3. *Dentaria laciniata* Muhl. ('irregularly cut')
Cut-leaved Toothwort
Found throughout the state. Native. April–June
Specimens examined. — St. Clair Co. (C. K. Dodge, 1898); Ingham Co. (C. F. Wheeler, 1893); Keweenaw Co. (O. W. Farwell, 1888); Ingham Co. (E. J. Cole, 1895); Gratiot Co. (C. F. Wheeler, 1880); Genesee Co. (D. Cooley, 1840); Cass Co. (H. S. Pepoon, 1905); Clinton Co. (G. H. Hicks, 1889); Marquette Co. (Bronson Barlow, 1901); Washtenaw Co. (B. A. Walpole, 1918); Kent Co. (H. M. Bailey, 1891; Schoolcraft Co. (C. K. Dodge, 1917); Kent Co. (C. W. Fallass, 1897); Wayne Co. (C. Billington, 1914); Montcalm Co. (C. W. Fallass, 1881); Washtenaw Co. (C. Billington, 1918); Kent Co. (G. D. Sones, 1889); Jackson Co. (S. H. and D. R. Camp, 1897); Eaton Co. (B. A. Walpole, 1924); Lenawee Co. (B. A. Walpole, 1924); Kent Co. (E. J. Cole, 1896); Emmet Co. (C. W. Fallass, 1918).
Reported from Tuscola Co. (C. K. Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); Manistee Co. (F. P. Daniels, 1900); Charity Island (C. K. Dodge, 1910); Gogebic Co. (H. T. Darlington, 1920); Ionia Co. (I. W. Stacey); Oakland Co. (O. A. Farwell, 1907); Monroe Co. (O. A. Farwell, 1920).

## 27. Lunaria [Tourn.] L.

(Latin, 'moon-like')

| | |
|---|---|
| Pods oblong-lanceolate, acute or pointed at both ends; leaves all petioled; perennial | 1. *L. rediviva* |
| Pods broad elliptic, obtuse or rounded at both ends; upper leaves sessile; annual | 2. *L. annua* |

1. *Lunaria rediviva* L. ('renewed')
Perennial Satin-pod
Rare. Found near Cross Village bluffs near Lake Michi-

gan. Escape from gardens. Fugitive from Europe. May–July

Specimen examined. — Emmet Co. (C. W. Fallass, 1916).

2. *Lunaria annua* L. ('annual')
Satin-flower

Rare. Escape from gardens. Native of Europe. May–June

Specimen examined. — Ionia Co. (H. S. Greenloe, 1916).

## 28. Sinapis L.

(Greek, 'turnip')

| | |
|---|---|
| Leaves lyrate-pinnatifid; pedicels 8–10 mm. long; seeds yellowish; beak as long or longer than the valves | 1. *S. alba* |
| Leaves dentate or lobed; pedicels 4–6 mm. long; seeds blackish-brown; beak shorter than valves | 2. *S. arvensis* |

1. *Sinapis alba* L. ('white')
*Brassica alba* L. Boiss.
White Mustard

Occasional escape from cultivation. Adventive from Europe. Summer

Specimens examined. — Washtenaw Co. (B. A. Walpole, 1920); Kent Co. (C. W. Fallass, 1894); Ingham Co. (B. A. Walpole, 1923); Kent Co. (E. J. Cole, 1898).

Reported from Wayne Co. (O. A. Farwell, 1900); Berrien Co. (M. A. C., 1920); Ionia Co. (I. W. Stacey); Keweenaw Co. (O. A. Farwell, 1888); Macomb Co. (O. A. Farwell, 1923); Marquette Co. (O. A. Farwell, 1895).

2. *Sinapis arvensis* L. ('inhabiting ploughed fields')
*Brassica arvensis* (L.) Ktze.

Found throughout the state. Adventive from Europe. May–November

Specimens examined. — Cheboygan Co. (F. C. Gates, 1911); Otsego Co. (E. A. Bessey, 1912); St. Clair Co. (C. K. Dodge, 1894); Keweenaw Co. (O. A. Farwell, 1888); St. Joseph Co. (C. F. Wheeler, 1890); Ingham Co. (C. F. Wheeler, 1900);

Washtenaw Co. (B. A. Walpole, 1918); Midland Co. (E. A. Bessey, 1915); Saginaw Co. (I. P. Robinson, 1914); Kent Co. (C. W. Fallass, 1897); Wayne Co. (C. Billington, 1915); Clare Co. (B. A. Walpole, 1924); Eaton Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1897).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Kent Co. (E. J. Cole, 1901); Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1915); Tuscola Co. (C. K Dodge, 1908); Wayne Co. (O. A. Farwell, 1900); Manistee Co. (F. P. Daniels, 1900); Mackinac Island (C. K. Dodge, 1912); Oakland Co. (O. A. Farwell, 1912); Isle Royale (W. S. Cooper, 1910); Shiawassee Co. (E. A. Bessey, 1914); Antrim Co. (M. A. C., 1913); Midland Co. (M. A. C., 1915); Genesee Co. (M. A. C., 1914); Mecosta Co. (M. A. C., 1916); Sanilac Co. (M. A. C., 1917); Calhoun Co. (M. A. C., 1914); Gogebic Co. (H. T. Darlington, 1919); Charlevoix Co. (M. A. C., 1922); Berrien Co. (Charles Brown, 1896); Manistee Co. (M. A. C., 1914); Ionia Co. (I. W. Stacey); Muskegon Co. (C. D. McLouth, 1896).

### 29. Eruca [Tourn.] L.

(Latin name for some crucifer)

*Eruca eruca* (L.) Britton

Garden Rocket

Frequently in waste places. Adventive from Europe. May–October

Specimens examined. — Allegan Co. (H. Y. Finch, 1902); Washtenaw Co. (C. Billington, 1919); Calhoun Co. (W. G. Shepherd, 1912); Jackson Co. (W. W. Brown, 1912); St. Clair Co. (C. K. Dodge, 1910); Tuscola Co. (E. A. Bessey, 1912); Otsego Co. (E. A. Bessey, 1912); Lapeer Co. (E. A. Bessey, 1912); Lenawee Co. (E. A. Bessey, 1912).

Reported from Manistee Co. (M. A. C., 1912); Oscoda Co. (M. A. C., 1911); Sanilac Co. (M. A. C., 1911); St. Joseph Co. (M. A. C., 1911); Mason Co. (M. A. C., 1911); Oakland Co. (O. A. Farwell, 1913).

### 30. Erucastrum

('resembling Eruca')

*Erucastrum nasturtiifolium* (Poiret.) Schultz. ('nasturtium-leaved')

*Brassica erucastrum* Vill.

Locally found along railroads. Fugitive from Europe. June

Specimen examined. — Washtenaw Co. (O. A. Farwell, 1922).

### 31. Brassica [Tourn.] L.

(Latin, 'cabbage')

| | |
|---|---|
| Upper leaves sessile, none clasping the stem; plants essentially green; leaves mostly thin; flowers small | |
| Pods appressed, slender, erect; 1–2.5 cm. long, beak 3–4 mm. long | 1. *B. nigra* |
| Pods not appressed, divergent; 2–5 cm. long; beak 5 mm. long or none | 2. *B. juncea* |
| Upper leaves clasping the stem by auricled base; plants blue-green or glaucous-blue; leaves usually thick; flowers large | |
| Root large fleshy; lower leaves hairy not glaucous, upper glaucous and glabrous | 3. *B. rapa* |
| Root not enlarged; a straight tap root; flowers 1.5–2 cm. across, light yellow; young radical leaves sparsely setose-hairy; leaves deeply scalloped; sepals not appressed, not saccate | 4. *B. napus* |
| Root fusiform or branched; flowers larger, 1.5–2.5 cm. long, white or whitish yellow; young radical leaves glabrous; leaves less deeply scalloped; sepals appressed, saccate | 5. *B. oleracea* |

1. *Brassica nigra* (L.) Koch. ('black')

Black Mustard

This plant is much more common in the state than the number of plants in the herbaria shows. Naturalized from Europe. June–November

Specimens examined. — Washtenaw Co. (E. C. Allmendinger, 1860); Jackson Co. (A. J. Pieters, 1888); St. Clair Co. (C. K. Dodge, 1912); Wayne Co. (C. Billington, 1915); Oakland Co. (C. Billington, 1916); Emmet Co. (Wilbur Smith, 1911); Kent Co. (E. J. Cole, 1901); Emmet Co. (C. W. Fallass, 1918).

Reported from Van Buren Co. (H. S. Pepoon, 1907); School-

craft Co. (C. K. Dodge, 1915); Tuscola Co. (C. A. Davis, 1908); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Manistee Co. (F. P. Daniels, 1900); Antrim Co. (M. A. C., 1913); Mecosta Co. (M. A. C., 1913); Ionia Co. (I. W. Stacey)

2. *Brassica juncea* (L.) Cosson. ('rush-like')
Indian Mustard
Infrequently found in the state. Naturalized from Asia. May–July

Specimens examined. — Gogebic Co. (H. T. Darlington, 1919); Washtenaw Co. (B. A. Walpole, 1919); Emmet Co. (C. W. Fallass, 1923).

Reported from Kent Co. (E. J. Cole, 1901); Lapeer Co. (Mrs. M. Owen, 1904); St. Clair Co. (W. S. Cooper, 1904); Muskegon Co. (C. D. McLouth, 1897).

3. *Brassica rapa* L. ('turnip')
*Brassica campestris* L.
Turnip
Escape from cultivation throughout the state. Native of Europe. Summer

Specimens examined. — Macomb Co. (D. Clark, 1878); Van Buren Co. (H. S. Pepoon, 1905); Jackson Co. (S. H. Camp, 1894); Ingham Co. (C. D. Smith, 1898); Washtenaw Co. (B. A. Walpole, 1918); Cheboygan Co. (J. H. Ehlers, 1917); Gratiot Co. (C. A. Davis, 1892); St. Clair Co. (C. K. Dodge, 1913); Emmet Co. (C. W. Fallass, 1884); Washtenaw Co. (C. Billington, 1919); Oakland Co. (C. Billington, 1916); Genesee Co. (E. E. Sherff, 1909); Kent Co. (E. J. Cole, 1901).

Reported from Keweenaw Co. (O. A. Farwell, 1904); Wayne Co. (O. A. Farwell, 1900); St. Joseph Co. (F. P. Daniels, 1902); Manistee Co. (F. P. Daniels, 1900); Montcalm Co. (M. A. C., 1913).

4. *Brassica napus* L. ('turnip')
Rape
Occasional escape in the state. Fugitive from Europe. April–October

Specimens examined. — Ingham Co. (C. F. Wheeler, 1891); Washtenaw Co. (B. A. Walpole, 1919); St. Clair Co. (C. K. Dodge, 1916); Wayne Co. (C. Billington, 1918).

Reported from Van Buren Co. (H. S. Pepoon, 1907); Ionia Co. (M. A. C., 1917); Osceola Co. (M. A. C., 1917); Sanilac Co. (M. A. C., 1913); Mecosta Co. (M. A. C., 1917).

5. *Brassica oleracea* L. ('pot herb')
Cabbage
Occasional escape from cultivation. Native of Europe.
May–September

Specimens examined. — Macomb Co. (D. Cooley, 1848); St. Clair Co. (C. K. Dodge, 1912); Washtenaw Co. (B. A. Walpole, 1919).

## 32. Diplotaxis DC.

(Greek, 'double rows')

Pods stipitate; stems leafy to the inflorescence; pedicels 2–3 times as long as the flowers ..... 1. *D. tenuifolia*
Pods not stipitate; stems leafy at the base; pedicels as long or slightly longer than the flower ..... 2. *D. muralis*

1. *Diplotaxis tenuifolia* (L.) DC. ('slender-leaved')
Wall Rocket
Adventive from Europe. June–August
Specimen examined. — St. Clair Co. (C. K. Dodge, 1912).

2. *Diplotaxis muralis* (L.) DC. ('pertaining to walls')
Sand Rocket
Adventive from Europe. June–August
Specimens examined. — St. Clair Co. (C. K. Dodge, 1916); Sanilac Co. (E. A. Bessey, 1913); Washtenaw Co. (C. Billington, 1917).

Reported from Kent Co. (E. J. Cole, 1901); Wayne Co. (O. A. Farwell, 1900).

## 33. Raphanus [Tourn.] L.

(Greek, 'quick appearing')

Flowers yellow, fading to white; pods 4–10-seeded; longitudinally grooved ..... 1. *R. raphanistrum*

Flowers pink or white; pods 2–3-seeded; not longitudinally grooved ..... 2. *R. sativus*

1. *Raphanus raphanistrum* L. ('radish-like')
Wild Radish
Infrequently found in waste places of the state. Naturalized from Europe. Summer

Specimens examined. — Washtenaw Co. (C. D. La Rue, 1916); St. Clair Co. (C. K. Dodge, 1899); Kent Co. (E. J. Cole, 1898); Washtenaw Co. (B. A. Walpole, 1918).

Reported from Dickinson Co. (G. H. Coons, 1909); Tuscola Co. (C. A. Davis, 1908); Wayne Co. (O. A. Farwell, 1900); Genesee Co. (M. A. C., 1911).

2. *Raphanus sativus* L. ('cultivated')
Garden Radish
Escape from gardens occasionally. Native of Asia. June–October

Specimens examined. — Macomb Co. (D. Cooley, 1848); Washtenaw Co. (B. A. Walpole, 1918); Cheboygan Co. (J. H. Ehlers, 1917); Emmet Co. (C. W. Fallass, 1923); Kent Co. (E. J. Cole, 1892).

Reported from Van Buren Co. (H. S. Pepoon, 1907).

## 34. Cakile [Tourn.] Mill.

(Old Arabic name)

*Cakile edentula* (Bigel.) Hook. ('toothless')
American Sea-rocket
Found along the entire lake coast of Michigan. Native. Summer

Specimens examined. — Muskegon Co. (E. A. Bessey, 1916); St. Clair Co. (C. K. Dodge, 1893); Berrien Co. (C. F. Wheeler, 1890); Emmet Co. (D. F. Wheeler, 1890); Arenac Co. (C. F. Wheeler, 1900); Huron Co. (C. A. Davis, 1896); Ottawa Co. (E. J. Cole, 1895); Muskegon Co. (Miss Noppin, 1870); Ottawa Co. (C. Billington, 1918); Ottawa Co. (G. D. Sones, 1889); Emmet Co. (E. J. Cole, 1898); Wayne Co. (Mary Fallass, 1893); Mason Co. (Ralph Chaney, 1910); Berrien Co. (C. F. Milspaugh,

1914); Van Buren Co. (F. W. Johnson, 1914); Monroe Co. (B. A. Walpole, 1920); Allegan Co. (B. A. Walpole, 1924); Grand Traverse Co. (B. A. Walpole, 1924); Emmet Co. (C. W. Fallass, 1893).

Reported from Schoolcraft Co. (C. K. Dodge, 1915); Chippewa Co. (C. K. Dodge, 1914); Tuscola Co. (C. K. Dodge, 1908); Manistee Co. (F. P. Daniels, 1900); Charity Island (C. K. Dodge, 1910); Sanilac Co. (M. A. C., 1920); Allegan Co. (M. A. C., 1922); Muskegon Co. (C. D. McLouth, 1896).

Michigan State College
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# ECOLOGY OF GLEN LAKE AND SLEEPING BEAR REGION

WARREN G. WATERMAN

## I. GEOGRAPHY AND GEOLOGY

### *A. General Location*

THE region under consideration is located at the west end of Leelanau County, Michigan, about twenty-five miles west of Traverse City. It is roughly eight miles by five, bounded on the west and north by Lake Michigan, on the south by a range of hills and on the east by the dissected edge of a plateau (Map 2).

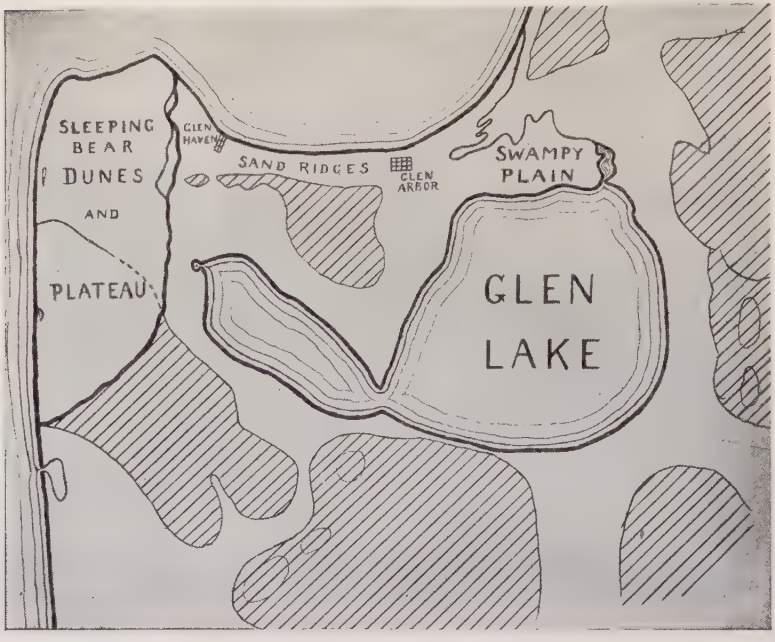
The southwest corner is located on Lake Michigan four miles north of the town of Empire, at the point where the southern ridge ends in a steep bluff in the lake. From this spot the shore runs north about four miles around Sleeping Bear Point, well known by sight to all who travel by water along the east side of Lake Michigan. Thence it bends southeast with a sweeping curve around the south side of Sleeping Bear Bay and continues north again toward Pyramid Point. On the shore of the bay are the little settlements of Glen Haven, about a mile east of the point, and Glen Arbor about two miles farther east.

The southern ridge runs from Lake Michigan eastwardly eight miles until it reaches the hills which mark the edge of the plateau. These extend almost due north to the shore of Sleeping Bear Bay, about two miles northeast of Glen Arbor.

### *B. Geography*

The region may be described as a horseshoe-shaped depression with its opening toward the north. The center of the depression is occupied by Glen Lake, which has the peculiar shape of a frying-pan with a bent handle. The circular body or pan lies to the east, is about four miles in diameter and is said to be two

hundred feet deep. The handle, about two and one half miles long and three quarters of a mile wide, makes an angle of about 110 degrees with the central line of the circular portion and is not over twenty feet deep. Between the arms of the lake is a triangular hill eight hundred feet high and two miles long from east to west, known as the Day Hills, from Mr. D. H. Day of Glen Haven.




Map 2. Glen Lake Region

The lined areas represent moraines. The solid line surrounding these areas is not an exact contour line, but represents an elevation of about fifty to seventy-five feet above Lake Michigan

On the west between Glen Lake and Lake Michigan is a plateau, consisting partly of gravel and partly of blown sand, which constitutes the Sleeping Bear Dune area (Map 3). North of Glen Lake, low sandy plains extend from Sleeping Bear Point to the upland east of Glen Arbor. No streams of any size flow

MAP 3. Sleeping Bear Dune Region

Horizontal lines = bare gravel-covered plateau; horizontal dashes = moraine more or less covered by blown sand; vertical lines = low gravel beaches; oblique dashes = old fixed dunes. Curving lines on unmarked areas indicate roughly the contours on sand ridges.

into the lake and the outlet meanders sluggishly across the eastern sand plains and enters Lake Michigan about two miles northeast of Glen Arbor.

### *C. Geology*

The uplands and ridges of the region form part of the Manistee Moraine, with the elevations trending in general from northwest to southeast. As the present level of Glen Lake is only about twenty feet above Lake Michigan, the basin was under water during the Lake Algonquin stage. The eastern part of Glen Lake was apparently a short but deep glacial valley, perhaps a sort of gigantic kettlehole. The eastern part of the lake plains would seem to be a harbor-bar, built by Lake Algonquin of materials from the bordering moraines. On account of its very slight depth the western arm of Glen Lake and the plains between it and Lake Michigan were probably of glacial origin, an extension of the moraine to the west.

The morainic ridge south of Glen Lake trends northwest and makes an acute angle with the shore of Lake Michigan. For a mile back from the shore the top of this ridge has been blown away by the prevailing southwest winds, so that it is now a flat-topped plateau with an average elevation of four hundred feet above the lake. The shape of the morainic portion of the plateau is that of a scalene triangle with its base about two miles long on the lake and its apex about a mile east. The eastern side and the northeast corner of the plateau have been extended by sand blown from the top of the ridge, and the edge of the moraine has been so obscured by this sand that it cannot be determined with any certainty. The north side of the present plateau now extends in an irregular line almost due east from the corner of the glacial moraine on Lake Michigan to the plain west of Glen Lake. Just beyond the northeast corner is the first low point on the east edge of the dunes. As it furnishes the most accessible ascent to the plateau, it has been chiefly used by visitors and is popularly called the "Entrance to the Bear." At the south angle of the morainic triangle is a small dune complex and in the center of the west side above the lake

is a small relict forested dune. The dune has a slight resemblance to an animal lying on its side with its head to the north. From this resemblance the dune received from the Indians the name of Sleeping Bear and the name was later extended to the whole plateau and to the point at its northern end (Pl. XXI, Fig. 1).

The morainic deposit consists of sand with a slight admixture of pebbles and boulders, and an occasional layer of water-washed gravel. As the sand was blown away, the pebbles remained on the surface and gradually concentrated there, so that the top of the plateau is covered by a fairly continuous layer of these pebbles. Most of the pebbles have lain in their present position, perhaps for thousands of years, and the constant friction of the blown sand has produced the characteristic features of desert pebbles. Many of them show a triangular, pyramid-shape ("dreikanten") and the harder specimens have received the glaze known as "desert biscuit," while the softer limestones and sandstones show all kinds of flutings and differential erosion.

At present the layer of pebbles protects the upper surface of the sand and the rate of removal of sand by the wind is probably very slow. Sand is all the time being blown across the plateau from the bluff and it is temporarily deposited in little mounds. These move slowly with the wind, so some spots are always being covered by fresh sand and others being laid bare as the mounds move on. The west side of this plateau rises as a bluff from Lake Michigan with a uniform steep slope and is cut by several large drainage gullies. The east side of the plateau, extended possibly one quarter to one half of a mile by blown sand, now ends in a steep lee slope of sand. This is advancing toward Glen Lake, in some places as rapidly as six feet a year, covering farm lands and forests in its progress (Pl. XXI, Fig. 2).

To the north the plateau drops rather suddenly in a succession of steps almost to the level of Lake Michigan and continues a mile or so to the north forming the tip of Sleeping Bear Point. This plain was all under water in the time of Lake Algonquin and probably represents a terrace formed by the waters of that

lake. Later stages of the post-glacial lakes are shown by several lower terraces and beaches, the main one being apparently of Nipissing origin and the lower ones of later date.

Most of this plain has been covered by sand blown from the top of the plateau. The bulk of the sand is still moving, and it has piled up in a number of high dune ridges in the center and on the eastern side. On the northeast, two of these ridges have reached the shore and occasionally large portions of their lee slopes slump off into the lake. The most recent of these slumps occurred in 1915, and it was estimated that at that time two hundred acres disappeared under water.

On the western shore of this plain there are several relict fixed dunes apparently very ancient, while on the eastern edge the moving dunes are encroaching on another series of fixed dunes probably much later in date than those of the west side.

In the central region there are also several blown-out troughs and on the sides of these troughs superposed soil-lines may be observed — in one case as many as four — so that the vegetational history of this area is evidently very complex (Pl. XXII, Fig. 5).

The curving shore between Sleeping Bear Bay and the moraine north of Glen Lake is about a mile in width and is covered by low sand ridges which were formed as dunes while the post-glacial waters were receding. The surface of the eastern half of this plain, through which flows the outlet of Glen Lake, is very flat and swampy but even there, sand ridges are found along the shore of Lake Michigan.

## II. PLANT COMMUNITIES OF THE GLEN LAKE REGION

### *A. Upland Forest*

The uplands, as is usual in this part of Michigan, were originally occupied by a heavy beech-maple-hemlock which did not differ materially from that in regions already described (Quick, 1; Whitford, 4; Waterman, 2). Much of the forest has been removed, but two tracts still remain which have been scientifically forested by Mr. D. H. Day and the product worked up in a little saw-mill at the northwest end of the west area of

Glen Lake. Where the ground was level and conditions mesophytic the trees, especially the hemlock (*Tsuga canadensis*), grew to very large size. In accessible localities all these original trees have been cut, but in most cases the remaining trees have been protected and the forests are growing up into a similitude of their original condition.

The only unusual feature in the floristic content of this forest is the presence of specimens of the moosewood, or mountain maple (*Acer pennsylvanicum*) on the northern slope of the Day Hills. The trees observed were near the trail leading up to the fire-warden's tower and reached six or eight inches in diameter and forty or fifty feet in height. As the north face of these hills is very steep and the ground protected from exposure to heat and drying out, this constitutes the most favorable locality in the region in which to look for this species.

### *B. The Sand-Ridge Region*

This term is used to cover the low flat strip which lies north of the Day Hills and extends from the east front of the Sleeping Bear Dunes to the edge of the upland on the east. While it is uniform in topography and surface appearance, geologically the eastern and western portions differ materially in origin and this difference is possibly reflected in the vegetation. The eastern third of this region represents the surface of a harbor-bar formed in Algonquin times, and its drier portions were originally covered by a well-developed pine-oak forest. This forest has remained relatively uninjured on the whole, although the presence of the village of Glen Arbor makes it hardly probable that it is still in original condition. It has not been seriously injured by fires and many of the original trees still stand.

Its floristic content is similar to that found on the Platte Plains twenty miles to the southwest (Waterman, 3). The pines are *P. strobus* and *P. resinosa* in the more mesophytic portions and the jack pine (*P. banksiana*) in more xerophytic localities. The oaks are *Quercus alba, Q. rubra* and *Q. velutina.* There are, however, very few specimens of the red maple (*Acer rubrum*) and no indications that they were ever as numerous as on the

Platte Plains. Here, as in the Platte Plains region, the upland forest had begun to invade the sandy plain from the morainic uplands to the east and southeast, but there was very little mingling at the northern edge of the Day Hills moraine.

The areas surrounding the meandering outlet of Glen Lake are low and swampy from Glen Lake to the Michigan shore. The central portion of the swampy plain has several extensive bogs with a dense growth of tamarack (*Larix laricina*) and arbor vitae (*Thuya occidentalis*). Around these is a peripheral belt in which elm (*Ulmus americana*) and ash (*Fraxinus americana*) mingle with water-tolerant species of the upland forest on the east and west, and of pine-oak forest on the north.

Owing to the protection furnished by the moraines on the south, there are no dunes along the shore of Sleeping Bear Bay and the sand-ridge vegetation originally extended almost to the beach. Pines and oaks still grow to full size to within a few hundred yards of the open sand, but the last specimens are scattered and stunted, with a preponderance of jack pine. There follows a narrow belt of pine-juniper association on low sand hummocks to the broad flat beach.

The western portion of the sand ridge region is higher and drier than the eastern and geologically it is a terrace cut by the waves of Lake Algonquin from the north slope of the Day Hills moraine. The original growth was early cut for one half of a mile in every direction from Glen Haven so it is somewhat difficult to decide as to its original content. At present the vegetation consists chiefly of upright juniper (*J. communis*) with many stumps and occasional relict trees of jack pine.

Farther west, between the Glen Haven road and the east front of the dunes, the original vegetation still stands as a jack pine-juniper association. The broad beach is similar to that of the eastern portion of the region, and leads up to a low sand ridge which may represent an old lake sand-bar. Behind this there is a belt of jack pine two hundred yards wide extending from the front of the dunes to the lumber yard west of Glen Haven. The pines average twenty to thirty feet in height in fairly open stand, with a slight admixture of arbor vitae. The

upright juniper (*J. communis*) grows to a height of four or five feet and occasional specimens reach eight or nine feet.

Among shrubs *Cornus stolonifera, Shepherdia canadensis* and occasionally *Symphoricarpus racemosus* are found poorly represented where the trees are in close stand, but form clumps or small thickets when the ground is more open. Around the edges of the thickets and in other open spots the bearberry (*Arctostaphylos uva-ursi*) and creeping juniper (*J. horizontalis*) cover the ground in some places. Elsewhere the ground plants are more open in stand and include *Rosa blanda* and *R. acicularis, Monarda punctata, Cerastium sp., Potentilla anserina, Sedum sp.* and *Campanula rotundifolia.*

There are occasional moist troughs between the ridges and in these the dominant plants are *Juncus balticus,* a Lobelia and *Gentiana crinata.*

Farther from the shore we reach the edges of the hardwood forest which has extended out from the Day Hills moraine and the narrow lake plain between the moraine and the east front of the dunes. This originally extended in a triangular lobe for a quarter of a mile out onto the sand plain and had begun to climb the sides of the old fixed dunes. It was considerably cut during the early days and now consists of a tangle of second growth along the line of the lumber railroad. In some places it is being overwhelmed by fresh sand blown from the plateau, but in others it is almost in its original condition. It also contains a considerable admixture of arbor vitae probably from the swamp forest at the northwest end of the narrow area of Glen Lake.

## III. PLANT COMMUNITIES OF SLEEPING BEAR DUNE REGION

### *A. Moving Sand Areas*

The tops of the large sand ridges and many of the wind-swept plains, both on the plateau and on the northern plain, are practically plantless. These are localities from which sand is being removed so rapidly that it is impossible for pioneer plants to become established. On the lee slopes of ridges and hills the dominant plant is the pioneer dune-grass (*Ammophila arenaria*).

This generally grows in scattered colonies with open stand, though occasionally stretches of several acres are covered by fairly close stand, and might be called Ammophila meadows. The first plants to be found with the Ammophila are usually wild wormwood (*Artemisia canadensis*), *Solidago sp.*, puccoon (*Lithospermum gmelini*), sand-thistle (*Cirsium pitcheri*), sea rocket (*Cakile edentula*), and later *Anemone cylindrica*, a dune milkweed (*Asclepias sp.*), the harebell (*Campanula rotundifolia*) and *Zygadenus chloranthus*. *Orobanche fasciculata* is locally found in some abundance, growing on the roots of the wild wormwood. The usual shrubs are the sand cherry (*Prunus pumila*), and one or two willows (*S. syrticola* and occasionally *S. longifolia*), but they are scattered in stand and not very common.

The surface of the blown-sand areas, whether on the east side of the plateau or on the plain to the north, is very uneven and consists of a series of ridges generally extending from south to north, with a very gentle west slope and a steep lee slope on the east. Below these lee slopes protected valleys are frequently formed and in their bottoms conditions are more stable and in a few cases even mesophytic.

On the floors of these protected valleys we find the closest stand and most luxuriant vegetation occurring on a dune sand substratum. Calamovilfa and Andropogon are the chief grasses, with Artemisia and other species of the open sand communities making up the bulk of the plants. *Lilium philadelphicum* and *Hudsonia tomentosa* also occur occasionally in these localities, and Ammophila grows usually in open spots around the edges.

In an unusually mesophytic valley located on blown sand near the southeast edge of the plateau there are groves of large cottonwoods surrounding a luxuriant bed of beach sweet-pea (*Lathyrus maritimus*) and Ammophila. The sweet-pea grows in very close stand to an average height of two feet, while the Ammophila is relatively much less important in size or number. The stand is so dense that no other plants are found in the thickest part of the community, but around the edges the species are the same as in the other protected valleys.

Trees are very scarce on the open sand and are al-

most entirely cottonwoods (*Populus deltoides*). In this respect this region differs materially from the Platte Plains and Point Betsie Dunes (Waterman, 2, 3), in which the poplar species is *P. balsamifera*. In general the growth habit of the cottonwood is similar to that in other dune regions. On the sides or even tops of sand ridges they grow as individuals or in clumps and are in good condition, though of small size. These specimens apparently started at a lower level and have been growing up through the accumulating sand in the normal manner of dune cottonwoods. Some of these clumps will be found in localities from which sand is being rapidly blown away and in such cases the trees are in poor condition and frequently dying. In protected valleys there are usually a number of cottonwoods which are in good condition, though seldom of very large size.

On the gravel plains of the plateau there are a few very peculiar cottonwood communities in which the trees are low and stunted and very evenly spaced, so that they resemble orchards of small fruit trees. Investigation of conditions in the substratum indicates that they have originated by root propagation from parent trees long since dead. The trees average five to eight feet in height and are gnarled and sickly in habit.

The presence of any cottonwoods on this elevated plateau is something of a surprise, as it is usually assumed that the seeds can germinate only in a substratum saturated with water, and it is evident that no water could stand on these sand plains. The only explanation seems to be that occasionally a succession of rains with moderately high temperatures might occur at the fruiting season of cottonwood, and thus make possible the germination and establishment of a few isolated trees or small clumps.

Apart from the vegetation of the fixed dunes, which will shortly be described, there is only one specimen of conifer association in the whole region.

This is a grove located near the south end of the plateau and is a dense growth oval in shape about two hundred feet long by one hundred wide. *Abies balsamea* constitutes about 50 per cent of the tree species, with 15 per cent of *Pinus resinosa*, 10 per cent of *Juniperus communis*, 10 per cent of *Populus deltoides*,

Sand blown from the west slope has been deposited on the east side and heaped up around the bases of the dead cedars in the "neck" of the Bear, in some cases to a height of two or three feet in as many years. The north slope is a thicket of shrubs which a few years ago were shoulder-high and almost impassable. In 1925 they had been buried nearly half their height by blown sand and could be traversed in any direction.

The east side is covered with a dense thicket in which conifers and dicot shrubs predominate. The components of this association are chiefly *Thuya occidentalis* and *Abies balsamea,* with occasional specimens of *Tilia americana, Prunus virginiana, Sorbus americana* and *Betula alba.* At the bottom of the northeast slope there is a clump of gnarled specimens of *Populus deltoides.* Shrubs include *Cornus stolonifera* and *C. alternifolia, Viburnum opulus, Sambucus canadensis, Taxus canadensis, Celastrus scandens, Rhus toxicodendron, Rosa spp.* and *Arctostaphylos uva-ursi.* The thicket is so dense that there are few herbaceous plants, but *Smilacina stellata* is locally abundant and *Maianthemum canadense* is found in mesophytic spots.

2. Fixed dunes of the northern plain

The west side of the northern plain shows the remains of a line of dunes which bordered the shore from the base of the plateau nearly to the present end of the point. Most of these are recognizable today only by old soil-lines or parts of dead trees. But the southernmost dune is still in fairly stable condition, perhaps because it is under the lee of the plateau which rises in a gentle slope to a vertical height of four hundred feet. The dune is about the same length as the Sleeping Bear Dune, but is not as high or as wide. Its longitudinal profile shows the typical dune outline with a long windward slope to the south and a short steep slope on the north. On account of this shape, which somewhat resembles the famous Rock, the writer has named this dune the Little Gibraltar. The west side of the Little Gibraltar Dune has been eroded and shows the same steep slope as the plateau bluff. The east side is covered by a thicket of shrubs and grasses.

On the east side of the plain another row of fixed dunes can be traced from the low spot known as the "Entrance to the Bear" northward almost to the shore of Lake Michigan (Pl. XXII, Fig. 4). Toward the north these dunes have been more or less covered by the huge sand ridges which are moving across the central part of the plain, but the sand has not yet reached the dunes at the southern end. The southernmost member of this group is an old stabilized dune about two hundred yards long and one hundred wide just north of the "Entrance." It is fully stabilized on the east side and on top, but the west side has been considerably blown out by the winds. At the southeast corner a trough seventy-five feet wide and two hundred feet long has been cut by the southwest winds and extends well into the wooded portion of the east side.

The valley south and west of this dune is about two hundred yards wide and extends to the bottom of the moving dunes which are encroaching from the plateau. The vegetation consists largely of bunch-grass (*Andropogon scoparius*) with some Calamovilfa, Artemisia, *Cirsium pitcheri*, Lithospermum, Campanula, Anemone, Solidago, occasional patches of Arctostaphylos and *Juniperus horizontalis* and scattered specimens of *Salix syrticola* and *Prunus pumila*. At the base of the encroaching sand on the south there are several colonies of red clover (*Trifolium pratense*) which have probably been carried up the path at the "Entrance" by human means. The stand is open, but the character of its growth shows that it is evidently very mature.

This community extends up the west side of the dune, except where destroyed by wind action, until it mingles with the stunted growth of mixed conifers and of hardwoods from the east side. At the north end there are a number of arbor vitae trees strongly resembling those in similar position on the Sleeping Bear Dune. They are not as big and a larger proportion are still alive, but they are frequently blown out and many have fallen. On the eroded faces several old soil-lines are exposed and on the whole except for the presence of the hardwoods on the east side, it very closely resembles the Sleeping Bear Dune.

The east side is completely stabilized with a dense growth of

conifers, chiefly arbor vitae and fir balsam, with an occasional pine and pioneer hardwoods from the forest of the plain below. On the top, the trees are stunted and consist largely of *Prunus virginiana*, with some *Cornus stolonifera*, *Shepherdia canadensis*, *Prunus pumila* and *Rosa sp.* Grape and poison-ivy are abundant and bittersweet (*Celastrus scandens*) is common. Ground plants are scanty in the thickets, but in open spots toward the top the vegetation is similar to that of the meadow below on the west side.

Farther north the dunes of this chain have been greatly modified by wind action both of erosion and deposit. They have been blown out at many points, but at others they have been covered by the advancing slope of the sand ridges which are moving across the central plain. Their elevation above the plain becomes steadily less toward the north and finally they disappear under a broad, low hill of fresh sand which reaches the shore of Lake Michigan just east of the Coast Guard Station (Pl. XXII, Fig. 6). At one point about a quarter of a mile south of the shore, a low tongue of sand extends eastward from under the main lee slope onto the plain. From its shape and position it would seem to be the remains of a still older series of dunes which had been overwhelmed by the sand of this eastern chain, which in turn is being covered by the fresh dunes from the central region.

### *C. Plant Communities of Gravelly Plains*

1. Gravel plains of the plateau

These level stretches comprise all of the surface of the plateau which is not covered by the low moving hillocks of blown sand. The substratum is morainic sand with a very small percentage of pebbles, but the surface is covered by the concentrated layer of sand-polished pebbles and cobbles. The plant communities of these gravel plains are practically identical in content, and consist of bunch-grass (*Andropogon scoparius*), unevenly distributed and sometimes reaching 50 per cent; *Koeleria cristata*, 5 per cent; Calamovilfa, scanty and near sand hillocks; harebell, 20 per cent; goldenrod, 5 per cent; wild wormwood,

5 per cent, with smaller quantities of Zygadenus, Anemone, puccoon, and locally sand thistle, sea rocket, two species of milkweed, sand cherry and willows. Patches of gravel are occasionally found on the floors of protected valleys in the border zone between the plateau and the blown-sand area. In these spots the species are the same, but the stand is more dense and includes in addition Arctostaphylos, some *Hudsonia tomentosa*, and an occasional evening primrose (*Oenothera biennis*).

2. Northern plain

The western edge and the eastern two thirds of the northern area are covered by ridges of blown sand and fixed dunes, but in the west-central portion and the northern edge there are a number of flat, gravelly stretches which represent uncovered portions of former lake beaches. The largest of these is situated just east of the Little Gibraltar Dune and is oval in shape and about eight hundred yards in its east and west diameter by six hundred yards from north to south. The vegetation is very uniform throughout its whole extent and from its appearance it may be called a bunch-grass meadow. The bunch-grass is very abundant and constitutes 60 to 75 per cent of the whole vegetation, while the accompanying plants are about the same and in the same proportions as on the gravelly stretches on the summit of the plateau.

At the north end of the point are two other extensive gravel plains which were left bare by the recession of the lake in relatively recent times. The smaller one is just east of the tip of the point and is triangular, the longest side running about four hundred yards along the present beach, with the apex located about two hundred yards south. The southern border is marked by old soil-lines and shore-lines, but their appearance is constantly changing with the motion of the sand. Recently an old shore-line was uncovered with very ancient logs lying as if just thrown up by the lake, but a few years later it was completely covered again. The vegetation is very scanty, but the species are about the same as those of the other gravel plains.

East of this old beach is a high dune ridge along which sand

is rapidly moving, but the northern end has reached the shore and is being continually undermined by the waves. The little group of buildings of the Coast Guard Station is located at the northeast lobe of this ridge and the sand is advancing so rapidly that in 1925 it covered the track from the life-boat house to the beach and it was necessary to moor the life-boat offshore. East of this huge ridge is another old beach which is still low and moist, though several feet above the present level of the lake (Pl. XXII, Fig. 6). It is reported that it has been under water within the memory of man, but as it was not under water in 1916 when the lake water reached the highest level recorded since the eighties, the correctness of this story does not seem probable. This beach is heart-shaped and is about two hundred yards across in either direction. It extends from the central sand ridge to the ridge which is covering the north end of the eastern line of fixed dunes. The vegetation is the same as that of the other beaches.

## IV. DEVELOPMENT OF VEGETATION (GENETIC ECOLOGY)

### *A. The Glen Lake Region*

The history of revegetation after the final retreat of the glaciers has been the same in this region as in other parts of Michigan similarly situated (Waterman, 3). The advance of vegetation followed the melting ice more rapidly along the moraines, especially on a rich, moist substratum, but was relatively slow on sandy stretches and in aquatic habitats. Thus we find the most advanced stages in mesophytic valleys, between ridges and on lake plains. Relicts of the pine-oak stage are still to be seen on exposed bluffs and hilltops in the climax forest as well as on occasional sand-ridge areas along the shore.

On the swampy plain of the Glen Lake bar, the aquatic succession has progressed to the swamp forest and bog forest stages in suitable localities. Along the edges of such formations, plants of the upland forest have begun to invade the swamp communities.

Succession was naturally slowed down on the unfavorable

substratum of the sand-ridge region and one will pass through a horizontal series of stages in going from the Day Hills moraine through the pine-oak ridges to the beach. The conditions of the substratum may have had some effect on development in this region as the succession before the arrival of the white settlers was apparently more advanced on the more favorable substratum at the eastern end. The pines and oaks were larger and flourishing around the outlet of Glen Lake, but became more and more stunted toward the west. West of the Glen Haven road there are no oaks and apparently never have been, while near the front of the dunes the vegetation is a low jack pine-juniper association. A tongue of the climax forest pushed along the narrow plain northwest of the smaller arm of Glen Lake, but its content was influenced to some extent by swampy conditions around the end of the lake. This mixed forest has sent some invaders up the east slope of the old fixed dune on the west side of the northern plain, but it did not extend far to the north on the sand-ridge region.

### *B. The Morainic Plateau*

The outstanding environmental features on this plateau are elevation, exposure and rapid removal of sand. When the glaciers retreated, the top of the moraine was probably rounded and higher than at present. Wind erosion must have begun at once and before the forest could have reached this end of the moraine, and it is unlikely that the major part of the plateau has ever had any more advanced vegetation than at present. At the southern end of the plateau an old soil-line under the southern perched dune may be the remains of the humus of that forest and borings might show that it extended toward the northeast under the present accretions of blown sand.

The vegetation of the present gravel plains is very similar to that of the grass-meadow stage at the base of the northern fixed dunes. The latter represents an advanced stage of the open sand succession, but on the gravel plains it appears to be a pioneer stage. As these plains are being crossed by low hummocks and ridges of moving sand and as some gravel stretches

are almost bare of vegetation, it seems reasonable to assume that these barren areas have recently been exposed by the removal of a cover of blown sand, and it is in those that we would look for pioneer stages. But the floristic content is everywhere practically the same and the only difference seems to be in the openness of stand. Where only one species is present, it is Andropogon in very scattered stand and this would seem to be the pioneer in this habitat. Studies of the roots of dune plants in a similar region near Frankfort have led the writer to infer that the substratum of a sandy moraine is slightly better supplied with available mineral nutrients than is the dune sand. Also the dune pioneer Ammophila does not appear on this gravel substratum even in the spots which seem to have been most recently uncovered, and Calamovilfa is found only in the vicinity of the sand hillocks. For these reasons it would appear that the bunch-grass association is the pioneer community on the gravel plains of the plateau. The cottonwoods are scattered and stunted and they seem to have become established under very exceptional conditions of moisture at the time of fruiting and to have been barely able to hold their own since. The colonies are apparently very old and are reproduced by growth of new shoots from roots. They may extend their limits slowly, but though they may cling to slight depressions, they show no signs of developing into a more advanced stage.

The lone conifer grove near the south end of the plateau occupies an anomalous position. It may perhaps be regarded as a relict of the conifer stage of the moraine vegetation which occupied a depression and so has been able to maintain itself when the rest of the plateau was leveled off. This is possible because it is so near the present moraine forest and is in the least exposed portion of the plateau.

The gravel stretches of the northern plain are so similar in their vegetation that the same explanation would seem to fit their case also. They are probably of more recent origin than those of the plateau, especially the two at the tip of the Point, but like those of the plateau they do not show signs of any other pioneer stage.

### *C. Perched Dunes*

The perched dune at the south end of the plateau is not a fixed dune. It shows no vegetation beyond the pioneer stage and its sand is apparently continually in motion, as that which is blown away is replaced by fresh sand brought up by the wind from the bluff and beach below. Probably the only reason why this dune can remain there at all is the slight protection afforded by the forest on the south slope of the moraine ridge which extends along this slope to the bluff on the lake shore.

The Sleeping Bear Dune shows great similarities in structure and vegetation to the fixed dunes of the northern plain. A study of these dunes suggests the following explanation. Each old soil-line in the substratum of a fixed dune represents a former ground surface on which vegetation had become sufficiently established to form a layer of humus several inches thick. This implies a stable condition for a number of years and perhaps centuries, followed by a change of conditions under which fresh sand was blown over and into the growing scrub or forest until a layer of pure sand varying in thickness from a few inches to many feet was laid down. This sand would accumulate rapidly until the woody plants were destroyed and then the top layers of sand would be removed as rapidly as deposited, and so this condition also might last for a long period of time. Then must come a period of relative rest in which the vegetation could again become established and another humus layer be developed. It is difficult to see how several soil-lines could be formed one above the other without this alternation of periods of rest and activity of the sand, with a consequent motion of the whole dune with the prevailing winds.

The case of the Sleeping Bear Dune is complicated by its position on the top of the bluff. It is regarded as probable that the moraine originally extended much farther out into the lake and that wave-erosion has cut it back to its present position. Whether this dune occupied a similar position then and has moved back with the bluff, or whether the present dune is only a remnant of a much larger one which has been cut away with

the bluff, cannot be stated at present. The only evidence of motion in the dune is the presence of the old soil-lines, and they can give no hint of the rate of that motion. The fact that the west face of the Sleeping Bear Dune is not parallel to the lake, but faces the prevailing winds, was not noted by earlier visitors and was not observed by the writer until this year. It is very important, however, as it shows that the chief erosional factor is now the wind. At the present level of the lake there is no wave-erosion at the base of the bluff, but when erosion was active it is quite possible that that agency was more potent than the wind and that under those conditions the west slope of the dune was continuous throughout with that of the bluff. This does not mean to imply that the recession of the south end of the Bear has taken place in the last five or six years, as it shows in photographs taken in 1920. It must have taken much longer than that and it may always have been present to some extent.

### *D. The Northern Plain*

The situation on the northern plain is governed by the same principles, but offers a different problem, because of its lower level and consequently its less exposed position, as well as because of its more recent origin.

The main portion of the plain occupies a very exposed situation at the tip of the point, but the southern portion is somewhat protected by the edge of the plateau. There is one fixed dune on the southwest corner of the plain and a row of such dunes along the east side. Dead trees and old soil-lines indicate that a similar line of fixed dunes, of which the Little Gibraltar was one, once occupied the west side also (Pl. XXI, Fig. 1). The persistence of the Little Gibraltar may be due to its protected position under the lee of the plateau.

The central portion of the plain is occupied by a belt of rapidly-moving, unstabilized dunes, but in this region there are several blow-outs which show a series of old soil-lines on their sides (Pl. XXII, Fig. 5). This would prove conclusively that there were at some time fixed dunes on all parts of the plain, and probably that they moved slowly across the plain from west to east.

This does not necessarily mean that the plain was completely covered at any one time or that the dunes moved uniformly and all at the same time, although their motion would seem to be dependent on changes in climatic conditions.

The wide expanse of moving sand in the center of the plain and the dying trees on the fixed dunes would seem to imply that the present era is favorable to sand activity and unfavorable to extensive plant growth. Whether or not the eastern line of dunes will be overwhelmed by this sand would then depend on the duration of present conditions and the relative diminution of the force of the wind on the east side of the plain. At present the eastern edge of the advancing sand runs in an irregular northeasterly direction from the northwest corner of the eastern edge of the plain. In view of its protected position it would seem as if the fixed dune at the "Entrance" might escape this invasion, although eventually it might be buried by sand from the plateau above it. By further detailed study it may be possible to correlate the various soil-lines and so patch together a more or less fragmentary history of the migrations of these dunes, and incidentally of the climatic changes in this region from the recession of the glaciers to the present.

## V. SUMMARY

The region under discussion is located around Glen Lake and Sleeping Bear Point at the southwest corner of Leelanau County, Michigan. It consists of a horseshoe-shaped depression in the western edge of the Manistee Moraine, with Glen Lake in its center, a morainic plateau two miles long by a mile wide, with its top leveled by the wind to a general elevation of four hundred feet above Lake Michigan; and a northern plain forming the top of Sleeping Bear Point and varying from five to twenty feet above the present lake level. This plain is almost entirely covered by dunes, some stabilized but the majority in active motion and of considerable height.

The substratum of the plateau consists of sand with a slight admixture of pebbles, the latter concentrated on the surface through the blowing away of sand by the wind. The vegetation

on the top of the plateau is very scanty and the chief community is an Andropogon association of very open stand, which seems to be the pioneer community on this sandy moraine substratum. The east side of the plateau has been extended by blown sand and carries the regular pioneer stages of dune sand vegetation.

The Sleeping Bear Dune, a fixed dune perched on the edge of the bluff above Lake Michigan, very closely resembles in structure and vegetation the fixed dunes of the northern plain. At present, sand is being blown away in large quantities from its west slope and deposited in its vegetation cover on the north and east sides.

The northern plain bears some very old fixed dunes on its western and eastern edges, but the center of the plain is a mass of rapidly moving sand. Under this sand can be seen old soil-lines which indicate the presence of fixed dunes at some time in the past. The northern edge of the plain at the very tip of the point shows lake beaches of recent geological origin.

The history of these dunes seems to be closely related to climatic conditions and a correct interpretation of this history might give important evidences as to the changes in climate from the end of the latest glacial recession to the present. It is to be hoped that this region can be protected as a state park so that these formations can be studied both at present and in the future, as they afford one of the best opportunities in the Great Lakes region for the study of dune action.

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## DESCRIPTION OF PLATES

### PLATE XXI

FIG. 1. Sleeping Bear region from the northwest. From right to left: Empire Bluff, Empire Valley, Sleeping Bear Plateau, northern plain with Little Gibraltar Dune

FIG. 2. Lee slope of east side of plateau, extended by blown sand

FIG. 3. West side of Sleeping Bear Dune with dead cedars and soil-lines. Forested side on right. Edge of bluff with Lake Michigan beyond, at extreme left

### PLATE XXII

FIG. 4. East side of northern plain. "Entrance to Bear" in distance, invading sands on right, mature bunch-grass meadow on left

FIG. 5. Blown-out sand dunes in center of northern plain showing old soil-lines

FIG. 6. Gravel beach at end of point between two high sand ridges. Coast Guard Station at extreme left

PLATE XXI

FIG. 1

FIG. 2

FIG. 3

PLATE XXII

FIG. 4

FIG. 5

FIG. 6

# CULTURAL LIFE-HISTORIES OF DIAPORTHE I*

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IN A previous discussion of the relationships within Von Höhnel's "Diaportheen," the writer (13) has pointed out that, although the genera Diaporthe and Melanconis have not been satisfactorily differentiated heretofore, yet there exist certain correlated characters in both the perithecial and conidial stages of the species of these genera which separate them into two distinct groups. The genus Diaporthe, it was shown, is distinguished by the presence of a more or less differentiated light-colored entostromatic area, bounded by a blackened zone, and by the presence of a pycnidial stage of the Phomopsis type in the life-history of its species. The genus Melanconis, on the other hand, possesses a sharply defined ectostroma, with no differentiated entostroma or blackened zone within the host bark, and a conidial stage belonging to the form genus Melanconium.

These correlations have held good in all the five species whose life-histories are given here. The four species possessing a differentiated entostroma and a dark marginal zone all produced pycnidial fruit bodies of the Phomopsis type. The single species, *Diaporthe marginalis* Pk., which showed the stromatic characters of the genus Melanconis, produced colored conidia in more or less open cavities of the Melanconium type.

## Diaporthe pruni E. & E.

This species is interesting as an example of the overlapping variation often occurring, among the species of this genus, on related host substrata. A great deal of confusion exists among the species of Diaporthe on Prunus and related genera. Von

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Höhnel (6, p. 387) in his discussion of these species considers that many of the thirty-two species described on these host genera are synonymous. Material of *Diaporthe pruni* E. & E. was collected by the writer on *Prunus virginiana* L. in the Catskill Mountains of New York. This material is identical with that described by Ellis (4, p. 141) as *D. pruni* (*N. A. F.*, 2d ser., No. 2822). This species is closely related to a group of synonymous species mentioned by Von Höhnel (6), including *D. patria* Speg., *D. aucupariae* Haszl. and *D. Woroniniae* Jacz., all of which occur on Sorbus. *Diaporthe impulsa* (Cke. & Pk.) Sacc., on Sorbus, is also closely related to this group. All these species have a practically identical stromatic configuration, but show slightly different ranges of ascospore and conidial measurements. These relationships will be discussed more fully after a consideration of the imperfect stage of *D. pruni*.

The stromata of *Diaporthe pruni* appear on the surface of the twig as numerous, laterally elongated, conical pustules which measure 0.7–3 × 0.3–0.7 mm. These pustules are erumpent through the closely adherent periderm as minute whitish discs, which soon become blackened, and which contain the fascicle of short cylindrical to conical ostioles. The perithecia are seated beneath a strongly developed ectostromatic disc which often contains a pycnidial locule (Pl. XXIII, Fig. 1). The perithecia are spherical to ovoid, measure 500–700 × 300–500 $\mu$, and lie wholly or partially immersed in the wood within a light-colored differentiated entostromatic area. This entostromatic area is effuse and bounded ventrally by a blackened zone some 2–3 mm. within the wood. Each perithecial cluster, however, is within, or beneath, an isolated pustulate extension of this basal entostroma. These pustulate extensions are formed within the bark tissue and are bounded by a continuation of the dorsal blackened zone upwards through the bark. The asci (Pl. XXV, Fig. 2) are clavate and measure 65–92 × 6–10 $\mu$. The spores (Pl. XXV, Fig. 3) are fusoid-elliptical, 2-celled, hyaline, constricted at the septum, and have a short, thick, evanescent appendage at each end which measures 4–8 $\mu$ in length. The spores measure 15–18 (23) × 4–5 $\mu$.

Suspensions of ascospores, in both sterile water and a nutrient solution, were sprayed on agar on October 8, 1923, from the material mentioned. No germination occurred in either case. Removal of the ascospore suspensions to a cold room for several days had no stimulating effect. The twigs themselves were then placed at 0–3° C. until November 3, when they were placed in a damp chamber at room temperature. Sprays of ascospores from these twigs were made on November 9. Twenty-four hours later these spores were germinating. They did not swell appreciably, measuring 21–23 × 6.5 $\mu$ at the time of germination. They had lost their appendages and were pushing out two to three germ tubes which measured 2–3 $\mu$ in diameter. The growth of one of these germ tubes usually predominated and soon branched in an irregularly dichotomous fashion. These branches ran more or less parallel to one another forming a characteristic spray-like fascicle of hyphae.

On January 3, 1924, a single ascus culture made on oat agar, which had begun to form stromata a few weeks before, was examined. The stromatic areas were raised 0.5–1 mm. above the surrounding surface. They were white at first, later taking on a tan color, and in some cases becoming greenish to olive. These stromatic areas were circular, confluent, or widely effuse, and were 0.3–5 mm. in diameter. Colorless drops of liquid, which later turned blackish, oozed out from these stromata. Shortly after these droplets became dark in color, spore formation began within the stroma. The locules formed within these stromata were flattened or spherical, and were surrounded by a thick wall-like area of dark-walled cells. These locules were lined with a layer of filiform conidiophores which bore conidia of the long-cylindrical, hamate, one-celled, beta type (Pl. XXV, Fig. 5), which measured 10–13 × 1.5–2 $\mu$. Only a few of the second or alpha type of elliptical-fusoid conidia (Pl. XXV, Fig. 4) were found in the pycnidia formed on agar. These conidia measured 10–11 × 2.5–3 $\mu$. The spore horns were yellowish.

On December 19, 1923, a steam-sterilized twig of *Prunus serotina* Ehrh. was inoculated from a single ascus culture. About

two weeks later stromata began to form about the point of inoculation and soon covered the entire twig. The stromata on twigs originated as ectostromatic cushions just beneath the periderm. About the same time that these ectostromata arose, an area of bark tissue was delimited beneath each ectostroma by the formation of a blackened zone of tissue. There then occurred a rich development of entostromatic mycelium within this delimited area, giving it the lighter color and more compact texture of these areas.

The pycnidial locules (Pl. XXV, Fig. 1) were formed within the ectostromatic tissue, or occasionally extended into masses of entostromatic mycelium within the surface bark layers. The ectostromatic tissue of the pycnidium was composed of hyaline to olive-green, closely interwoven hyphae. The locules formed in this tissue varied in shape. They were surrounded by a zone of smaller, darker-walled, pseudo-parenchyma cells, which formed a wall-like boundary. This wall-like tissue was lined within by a thin layer of hyaline hyphae, from which the filiform conidiophores arose. The conidia were of two types. In the smaller and younger locules there were formed chiefly the filiform, hamate, hyaline, one-celled, beta type of conidium (Pl. XXV, Fig. 5), which measured 10–15 × 1–1.5 $\mu$. In the larger and older pycnidia the conidia were chiefly of the narrow fusoid, hyaline, one-celled, alpha type (Pl. XXV, Fig. 4), which measured 10–16 × 2.5–3 $\mu$. The spore horns were white to yellowish. The yellowish spore horns were composed chiefly of the filiform beta type of conidium, while the white spore horns contained mostly those of the fusoid alpha type.

Ellis (4) gives the imperfect stage of *Diaporthe pruni* as *Cytospora pruni* Ell. & Dear. The specimen labelled "spermagonia" in the type material contains only the fusoid alpha type of conidium. From the foregoing data it can be seen, however, that the imperfect stage is clearly a Phomopsis with two types of conidiospores, and should be called **Phomopsis pruni** (Ell. & Dear.), comb. nov.

As already mentioned, Von Höhnel gives *D. patria* Speg., *D. aucupariae* Haszl. and *D. Woroniniae* Jacz. as synonymous

species. He gives the measurements of the ascospores of *D. patria* as 14–17 × 4–6 μ. European exsiccati of *D. patria*,[1] examined by the writer, showed ascospores 14–18 × 3–5 μ. A specimen of *D. aucupariae* (Herb. N. Y. St. Mus., *legit* E. T. & S. A. Harper, No. 2375) showed ascospores 13–19 × 3–4 (5) μ. This specimen also contains pycnidia in which were found elongate fusoid conidia measuring 18–24 × 2.5–3 μ. The type of *Diaporthe impulsa* (Cke. & Pk.) Sacc. (Herb. N. Y. St. Mus., *legit* Peck.) has ascospores 13–16 (18) × 3–4 (5) μ, and is accompanied by pycnidia containing elongate fusoid conidia, measuring 15–18 × 2.5–3.5 μ, and filiform hamate conidia measuring 10–16 × 1 μ. All these species have a similar range of ascospore measurements, and an identical stromatic configuration. None of these four species on Sorbus is given as having appendaged spores, and no appendages have been seen by the writer in a number of specimens examined. These appendages are very evanescent, however, and are hardly ever found in dried material. They are absent, in fact, from the type specimens of *D. pruni* and from other herbarium specimens of this species.

The ascospores of *D. pruni* show a greater variation in length than the preceding species and have appendages when fresh. Ellis (4) gives the ascospores as 15–20 × 3.5–5 μ. Specimens collected by the writer have shown a range of 13–23 × 3–5 μ. The conidial measurements of *D. pruni* agree with those given above for *D. impulsa*, but are smaller than those of *D. aucupariae*. In culture, on the same twig, the smaller pycnidia of *D. pruni* contained fusoid conidia 10–13 × 2.5–3 μ, while the larger locules contained such fusoid conidia measuring 13–16 × 2.5–3 μ. Various pycnidia on the type material of *D. pruni* showed fusoid conidia ranging from 13–19 × 2.5–3 μ. These facts show that the length of these fusoid conidia are variable over a fairly wide range. Whether the conidia associated with *D. aucupariae* represent a further extension of this range, or a separate species or form, can be determined only by further culture of the species on Sorbus. At present, therefore,

[1] Syd. Myc. Germ., Nos. 1914 and 2133; Pet. Fung. polonici, No. 349; All. & Schnab., Fung. Bav., Nos. 159 and 247.

*D. pruni* can be said to differ from *D. patria* only in the somewhat greater range of ascospore measurements and the presence of evanescent appendages.

**Melanconis marginalis** (Pk.), comb. nov.

This species was described by Peck (9) in 1886 as *Diaporthe marginalis* Pk. Material of this fungus was collected on *Alnus tenuifolia* Nutt., near Copeland, Idaho. Both the perfect and imperfect stage were found growing luxuriantly on piled brush, covering the twigs for long distances. The perithecial stromata (Pl. XXIII, Fig. 2) are scattered, circular-pustulate, 2–3 mm. in diameter, and consist of a central ovoid to fusoid disc, which is 1–1.5 mm. long, and is surrounded by a circular raised area caused by the bulging perithecia immediately beneath the periderm. The disc is whitish to yellowish-brown in age. The ostioles are black, hemispherical to conical, punctate, and usually arranged about the margin of the disc, between it and the adherent periderm. In the smaller discs the ostioles may be scattered and often nearly obliterate the disc. The perithecia are spherical to ovoid, and measure 400–450 × 300–400 $\mu$. They lie irregularly circinate beneath the central disc and are immersed in the unaltered bark tissue. There is no differentiated entostromatic area, and no marginal dark zone. The asci (Pl. XXV, Fig. 7) are clavate and measure 70–78 × 9–10.5 $\mu$. The spores (Pl. XXV, Fig. 8) are biseriate, fusoid-elliptical, two-celled, hyaline, constricted at the septum, and possess a short hyaline evanescent appendage at each end, which measures 3–4 × 2 $\mu$. The spores measure 15–18 (20) × 4.5–5.5 $\mu$.

Ellis (2, p. 222) described this same species in 1890 as *Diaporthe nivosa* Ell. & Holw. He gave the asci as measuring 60 × 12 $\mu$, and the spores as being 12–16 × 3–4 $\mu$, and without appendages. An examination of his exsiccati (*N. A. F.*, 2d ser., No. 2535) of this species shows this specimen to be in an immature condition, which accounts for these discrepancies. The two species are identical in all other respects.

The conidial stromata on Alnus, at the time of rapid spore formation, appear as spreading black masses, which consist of

the exuded conidia. The conidial stromata are lenticular to truncate-conical, 2–3 mm. in diameter, and are formed just beneath the periderm. The hymenial layer is formed upon a basal stromatic layer, which is usually strongly dome-shaped in the center. This dome-shaped center is often more strongly developed, and then breaks through the periderm as a sterile erumpent disc. In this case the hymenial layer is formed in shallow cavities on the flanks, and about the base of this central disc. The conidiophores are filiform, 20–26 × 1–2 $\mu$, and bear two types of spores. The more evident are the ellipsoidal to fusoid conidia (Pl. XXV, Fig. 9), which are dilute black, and measure 13–16 × 5 $\mu$. The second type (Pl. XXV, Fig. 10) is a small, cylindrical to spindleform, hyaline, one-celled spore, often somewhat curved, and measuring 8–13 × 1.5–2 $\mu$.

Sprays of ascospores of this fungus were made on March 1, 1923, on nutrient agar. Twenty-four hours later these spores were germinating by means of a germ tube from each end of the spore. Single spore cultures on six per cent oatmeal agar produced a whitish to light tan, superficial mycelial growth, and after 7 to 8 days small conidial pustules began to appear. These small masses of conidia were at first covered by a delicate hyphal membrane, but soon became exposed as a Melanconium-like mass which spread out over the surface. Within these spore-forming areas the conidia were cut off in numerous small clusters within the agar. The smaller hyaline type of conidia was not seen in the agar cultures.

On March 6, 1923, a suspension of germinating ascospores, in sterile water, was sprayed on a steam-sterilized twig of *Tilia americana* L. The first mycelial growth, of small radial colonies, was noted on March 13. By March 21, small black droplets of conidia were noticed. Similar spore production was obtained on sterile twigs of *Alnus glutinosa* Gaertn. inoculated from a single ascus culture. The conidial stromata (Pl. XXV, Fig. 6) were similar to those found in nature. The growth of the ectostromatic disc in these cultures was quite variable, depending upon the conditions of growth, the chief factor of which seemed to be the moisture relations of the culture. During the earlier

growth of the culture, when still moist, there is a rapid growth of the ectostromatic tissue. Under such conditions a hymenium is produced over its entire surface, which is usually dome-shaped in the central portion. Where growth is not so rapid, this central portion of the ectostroma pushes upward as a sterile disc and ruptures the periderm. The hymenium is then produced in shallow cavities upon its flanks, and about the base of this central cylinder or cone. After the culture has dried out to quite an extent, the later, still more slowly growing ectostromata, may remain entirely sterile. No perithecial initials were found in culture, but where these occurred in nature they were usually found beneath such sterile ectostromata, or occasionally beneath those with hymenial cavities on their flanks, but never where conidial formation was luxuriant and over the entire surface.

Where conditions are favorable for rapid growth and conidial formation, there is apparently a rapid exhaustion of the food supply without the formation of perithecia. Perithecial formation, therefore, takes place only when there is a slow absorption of food material, with a restricted formation of stromatic tissue, and a limited production of conidia, which leaves available a surplus food supply for their production.

The conidia formed on twigs in culture were of the two types found on Alnus in nature, but slightly smaller. The colored conidia measured 10–14 × 4.5 $\mu$, while the hyaline ones measured 6–9 × 1.5–3 $\mu$.

This species is also closely related to the *Melanconis alni* Tul. of Europe, which is given as having somewhat larger ascospores (18–25 × 5–8 $\mu$). The Tulasnes (12, p. 122) give *Melanconium sphaeroideum* Link. as the imperfect stage of *M. alni*. This Melanconium is given as having brown elliptical conidia measuring 10–13 × 6.5–7.5 $\mu$, and also cylindrical hyaline conidia measuring 6.5–8 × 1.5 $\mu$. There seems to be a great deal of confusion among the European exsiccati of this species. All those exsiccati which agree with the description of *M. alni*, however, show stromatic characters identical with those of *M. marginalis*. Some of these exsiccati (Rehm., *Ascom.*, No. 148 *d*; Von Höhn. herb., No. 4225, Aug. 25, 1902, and June 15, 1901)

show ascospores 13–18 × 3–5 μ, which agree with those of *M. marginalis*. Other exsiccati (Von Höhn. herb., No. 4225, June 25, 1898; Syd. Myc., March, Nos. 190 and 3837) show ascospores 17–22 × 4–7 μ, which agree more closely with the measurements of the Tulasnes for *M. alni*. Many of these exsiccati, again, show the conidial stage (*M. sphaeroideum*) which is decidedly distinct from that of *M. marginalis*. Von Höhnel (7) reports *Diaporthe marginalis* from Europe. His description and spore measurements (18–22 × 5–6.5 μ) might fit *M. alni* equally well, however. This material of Von Höhnel's, now deposited at the Farlow Herbarium, was examined by the writer, and the ascospores found to be somewhat smaller (16.5–18 × 5–6 μ). No conidial stage was found upon this material.

*Melanconis marginalis* seems to differ from *Melanconis alni* only in its somewhat lower range of ascospore measurements, and its production of dilute black fusoid conidia rather than elliptical brown ones, as in *M. alni*. A comparative cultural study of these European forms should be made to determine whether there are two closely related forms with different conidial stages, and if so, whether or not there are any correlated characters in the perithecial stages.

The dark-colored conidia of the species here discussed would place it in the genus Melanconis. The well-developed ectostromatic disc, the circinate perithecia immersed in the unaltered bark tissues, and the lack of any circumscribing zone, also relate it to the other species of Melanconis. The name **Melanconis marginalis** (Pk.), comb. nov., therefore, is proposed.

### Diaporthe sp.

The species here considered does not seem to agree with any species of Diaporthe so far described on Carya or Juglans. So many species of Diaporthe have been described, and so little is known in regard to the relationships of the various species to different host substrata, that the erection of new species in this genus can be only more or less uncertain and temporary until all the species of the genus have been studied comparatively.

Merely a description, and comparison of this species with related species, therefore, will be given here.

Material of this species was collected on *Carya glabra* (Mill.) Spach. near Ann Arbor, Michigan. The stromata were found on an old wound scar, and did not encroach upon the normal bark of the limb. The fungus appears superficially as numerous minute pustulate ruptures in the periderm, through which the short cylindrical ostioles penetrate. The ostioles are sometimes long filiform, and then usually lie horizontally between the periderm and the bark. The entostromatic areas (Pl. XXIII, Fig. 3) are effuse, lighter in color than the surrounding tissue, very irregular in outline, and bounded by a dark circumscribing zone. The perithecia are spherical and measure 380–460 $\mu$ in diameter. They are irregularly scattered or occasionally clustered, but usually collectively erumpent. The asci (Pl. XXVI, Fig. 2) are clavate, contain a refractive ring in their tip, and measure 65–70 $\times$ 8–9 $\mu$. The spores (Pl. XXVI, Fig. 3) are biseriate, fusoid-elliptical, usually inequilateral or slightly curved, two-celled, hyaline, constricted at the septum, and measure 16–20 $\times$ (3) 4–5 $\mu$.

In its stromatic characters, this species fits very well either *Diaporthe juglandina* (Fck.) Nit. or *Diaporthe tenuirostris* Nit., on *Juglans regia*. Nitschke (8, p. 281) gives the spores of *D. juglandina* as 13–15 $\times$ 3–4 $\mu$ when young and 16–18 $\times$ 4–5 $\mu$ when fully mature. The type of this species (Fck., *Fung. Rhen.*, No. 2156), however, has the spores recorded as 12 $\times$ 4 $\mu$, and a number of European exsiccati (Rehm., *Ascom.* No. 1233; Rab., *Fung. Eur.*, No. 4356; Krieg., *Fung. Sax.*, No. 1265) all show ascospores measuring 10–13 $\times$ 2.5–4 $\mu$. Nitschke (8, p. 293) gives the spores of *D. tenuirostris* as 13–14 $\times$ 3 $\mu$, and states that they are sometimes inequilateral. Authentic material of this species was not available to the writer, but Nitschke's description fits the species here considered in all respects except the smaller spore measurements. *Diaporthe apocrypta* (Cke. & Ell.) Sacc., on Carya, is given by Ellis (3, p. 434) as having ascospores 18–20 $\times$ 6 $\mu$. Through the kindness of Dr. F. J. Seaver of the New York Botanical Garden, the writer was able to examine

type material of this species. This material consists mostly of old perithecia. Only two perithecia were found containing ascospores, and each showed spores of a different type. In the perithecium with most abundant spores, the spores measured 11–13 × 4–4.5 μ. A second perithecium yielded a few spores measuring 16–18 × 5 μ, which agree more closely with the original description. As stated in the original description, *D. apocrypta* shows no dark line, differing in this respect from the species here described.

Sprays of ascospores from the material on Carya were made on agar on December 20, 1923. Twenty-four hours later these spores were all germinating by means of a single germ tube some 2.5 μ in diameter.

A single ascus culture on six per cent oat agar made on January 22, 1924, showed, on March 31, a few flattened-hemispherical stromata 2–2.5 mm. in diameter. Yellowish-white spore horns were exuded from these stromata. They were composed of hyaline interwoven hyphae, and many of them were variously blackened in part. The conidial locules formed in these stromata were irregular in shape. These locules were surrounded by a differentiated wall-like zone of dark-walled pseudoparenchyma cells. This wall-like area was lined within by a layer of fine hyaline hyphae from which arose the hymenium of long cylindrical conidiophores. The conidia found on agar were elongate ellipsoid to fusoid, one-celled, hyaline, and measured 8–10 (13) × 2–2.5 μ (Pl. XXVI, Fig. 4).

On January 9, 1924, a steam-sterilized twig of *Carya sp.*, with its base immersed in six per cent oat agar, was inoculated from a single ascus culture. This culture was kept at 0–3° C. for three months. It then showed numerous superficial stromata which, upon removal to room temperature, produced conidial spore horns. A similar culture made on May 14, and kept at room temperature, showed both pycnidia and mature perithecia when examined on June 10.

The first evidence of stromatic development is the formation of small cushions of ectostroma on the surface of the bark, just beneath the periderm. These ectostromata are conical to pul-

vinate, and 0.5–1 mm. in diameter. They rupture the periderm and, under the moist condition of the culture tube, often form superficial hemispherical stromata. These stromata are composed of intertwined, hyaline to brownish hyphae. The pycnidial locules (Pl. XXVI, Fig. 1) are flattened-lenticular, spherical, or irregular in shape, and are formed within the ectostroma or, more often, within the entostromatic tissue which is forming at the same time in the bark tissues beneath. The locules are usually surrounded by an irregular and indefinite zone of darker-colored hyphae, forming a wall-like area. The locules are lined with a hymenium of filiform conidiophores. Two types of conidia are formed. The most abundant, alpha type (Pl. XXVI, Fig. 4) is cylindric-fusoid, one-celled, hyaline, and measures 12–16 × 2.5 $\mu$. The second, beta type (Pl. XXVI, Fig. 5), which is apparently formed first, is filiform, curved or hamate, and measures 10–13 (18) × 1–1.5 $\mu$. The spore horns are light-yellow to pale-orange.

During the formation of the pycnidium there usually, but not always, appears a narrow darkened zone of tissue extending irregularly into the bark from the margin of the ectostroma. This zone, in this species, is formed by the local blackening of the walls of the bark cells, at the margin of the entostromatic areas. Where such zone is not formed, the dark cells beneath the pycnidium become disintegrated to a crumbly mass. The perithecial initials are formed within the widely effused entostromatic tissue produced within these delimiting blackened zones. These initials are sometimes laid down beneath the ectostromata, but are usually scattered irregularly, at various depths in the bark, either singly or in groups. This species shows a condition in which the perithecia are not as yet definitely oriented beneath the mechanical tissue of the ectostroma. The ostioles in culture were long-filiform and sinuous. Many species of Diaporthe show this tendency to form elongated ostioles under moist conditions of growth. The ostioles were usually erumpent in small clusters of 3 to 8. The mature ascospores formed in culture were more definitely curved or inequilateral than those found in nature, and measured 18–21 × 4–5 $\mu$.

DIAPORTHE FAGINEA (Curr.) Sacc.

This species is closely related to *Diaporthe oncostoma* (Duby) Fck., and differs only in the general character of the stromatic configuration. Material of *Diaporthe faginea* (Curr.) Sacc. was collected on twigs of *Fagus grandifolia* Ehrh. in the Catskill Mountains, near Phoenicia, New York. The stromata are small and thickly scattered. They are at first barely erumpent through the stellately ruptured periderm as a blackened disc. This disc contains a cluster of minute punctate ostioles which are occasionally somewhat elongated and sinuous. In age the brittle periderm may be thrown off, exposing the disc. The perithecia are spherical, 300–350 $\mu$ in diameter and have walls 13–15 $\mu$ thick. They are formed in small clusters in the upper bark tissues (Pl. XXIV, Fig. 2). The basal portions of the differentiated entostromatic areas are effused, and bounded by a dark marginal zone which often extends into the wood. Each cluster of perithecia, however, is within a pustulate extension of this basal entostroma. The asci (Pl. XXV, Fig. 12) are clavate and measure $52 \times 8$–$10$ $\mu$. The spores (Pl. XXV, Fig. 13) are biseriately arranged in the ascus, fusoid-elliptical, 2-celled, hyaline, constricted at the septum, and measure $12$–$16 \times 2.5$–$3$ (4) $\mu$.

Although Currey (1, p. 281; Pl. 48, Fig. 168) merely states that the spores of *Sphaeria* (*Valsa*) *faginea* are 12.5 $\mu$ in length, this appears to be that species so far as can be judged from the description.

Suspensions of ascospores from the material mentioned were sprayed on agar on January 3, 1924. Twenty-four hours later these spores were germinating by means of a single germ tube, 2.5–3 $\mu$ in diameter. The spores had not swollen.

A single spore culture on six per cent oat agar, made on January 7, showed conidial stromata on May 21. The conidial locules were formed in superficial hemispherical or pulvinate stromata, which were 1–2 mm. in diameter. These stromata were composed of a hyaline mycelium, with an outer layer of dark-walled hyphae. The locules within the stromata were either spherical, or in the shape of a hollow sphere, giving a

crescent-like cross-section. There was usually a zone of darkened hyphae about the margin of the locule, forming a wall-like boundary. The conidia in these pycnidia were of the fusoid alpha type (Pl. XXV, Fig. 14). They were one-celled, hyaline, and measured 9–12 × 2.5 $\mu$. A single ascus culture made on August 22, 1924, and kept at 3–10° C. until June 18, 1925, produced somewhat larger stromata containing one or more irregularly shaped locules. Two types of conidia were found in these pycnidia. The alpha type of conidia mentioned above measured 8–16 × 2.5–3 $\mu$. The second beta type (Pl. XXV, Fig. 15) were filiform, hyaline, variously bent or curved, and measured 26–40 × 1–2 $\mu$.

A steam-sterilized twig of *Fagus grandifolia* Ehrh. was inoculated from a single ascus culture on January 25. Pustules were first seen on this twig about February 15, and soon spread over the entire surface. They were formed as small conical ectostromata, 0.2–0.5 mm. in diameter, just beneath the periderm. There was formed in such a stroma an irregular locule surrounded by a wall-like zone of 4 to 5 rows of thick-walled, dark brown, pseudo-parenchyma cells (Pl. XXV, Fig. 11). Two types of conidia were produced, as on agar. The first type to be formed was the filiform, hyaline curved conidium, which was formed on long filiform conidiophores. These conidia measured 24–34× 1–1.5 $\mu$. In the later growth of the pycnidium the growth of the conidiophores was not so rapid; they were shorter, and their tips swelled to form the second or fusoid type of conidium, which measured 10–13 × 2.5 $\mu$. Conidia were formed intergrading between these two types, but the large majority could be distinguished as of one or the other type. The spores were exuded as short whitish spore horns.

### Diaporthe arctii (Lasch.) Nit.

The material from which cultures of this rather common species on herbaceous stems were obtained was collected on Actium near Ann Arbor, Michigan. The surface of the dead stems is blackened in the fruiting areas, and roughened by the numerous, projecting, cylindrical to conical ostioles. The peri-

thecia are spherical or somewhat flattened, and measure 250–500 $\mu$ in diameter. They are formed in the bark cortex or in the wood, within a widely effused entostromatic area (Pl. XXIV, Fig. 1). This entostromatic area is bounded by a ventral blackened zone which dips deeply into the wood, often to the pith. The dorsal blackened zone is visible as the blackened surface of the stem. These patches of entostroma vary in size, sometimes being small and irregular, or again including the entire surface of the stem for some distance. The perithecia are scattered singly and are separately erumpent. The asci (Pl. XXVI, Fig. 7) are clavate and measure 38–45 $\times$ 5–6 $\mu$. The spores (Pl. XXVI, Fig. 8) are biseriate in the ascus, fusoid-elliptical, two-celled, hyaline, slightly constricted at the septum, and characteristically inequilateral or slightly curved. The spores measure 13–16 $\times$ 2.5–3.5 $\mu$ when mature.

Sprays of ascospores of this species were made on agar on October 20, 1924. Twenty-four hours later these spores had germinated by means of a single stout germ tube, 3 $\mu$ in diameter.

The first cultures made on oat agar from a single ascus, on October 26, 1924, were not examined until June 13, 1925. At this time small pustulate stromata were found in the surface of the agar, but no spores were present. Other single ascus cultures on oat agar were made on November 1, 1925. One of these cultures showed whitish spore masses on November 30. This culture was examined on December 10. At this time there were numerous spherical masses of stromatic pseudo-parenchyma just beneath the blackened surface of the agar. These stromata, which were 125–250 $\mu$ in diameter, formed small pustulate swellings on the surface of the agar. Many of these stromata remained sterile, but in others conidial formation was initiated and irregular locules lined with a hymenium of filiform conidiophores were produced. A blackened zone, corresponding to the ventral dark zone present when growing on wood, was often present some 0.5 mm. beneath the surface of the agar, and running parallel to it. The region between this ventral zone and the blackened agar surface was richly interspersed with hyphae,

many of which had brownish walls. Only the hamate, filiform, hyaline, beta type of conidium (Pl. XXVI, Fig. 10) was produced on agar. These conidia measured 18–25 × 1 $\mu$.

On December 13, 1924, a steam-sterilized stem of Arctium was inoculated from a single ascus culture. This culture was examined on January 13, 1925, when numerous, crowded, minute pustules, exuding whitish to yellowish spore horns, were found. Most of the pycnidia on this stem contained only the hamate beta type of conidium found on agar. Some of the pycnidia, however, also contained a fusoid, hyaline, one-celled, alpha type of conidium (Pl. XXVI, Fig. 9), measuring 8–10 × 2–2.5 $\mu$. On November 9, 1925, two stems of Arctium, with their bases immersed in oat agar, were inoculated from a single ascus culture. On December 14, one of these stems showed a number of filiform ostioles of immersed perithecia, as well as numerous pycnidia. Only the hamate beta type of conidium was found in this culture.

The pycnidia (Pl. XXVI, Fig. 6) arise as small masses of stromatic mycelium, just beneath the periderm, within the upper bark layers. Conidial formation is soon initiated within these stromata, and a more or less flattened, irregularly shaped locule is formed. The apical portion of these stromata often breaks through the periderm and forms a small papillate erumpent neck. In culture the stroma is often strongly developed and may contain a number of irregular locules. Along with the formation of the pycnidia there occurs a blackening of the surface layers of the substratum, and following this the formation of a blackened zone about the margin of the entostromatic areas. These blackened zones, in this species, consist of a deposition of a brownish-black substance within the elements of the bark or wood. This substance is apparently excreted by large, brown, thick-walled hyphae, and seems to be of the same nature as the brownish pigment deposited in the hyphal walls.

The perithecia arise within the bark or the upper layers of the wood. They are not oriented in any way in relation to the pycnidial ectostromata, which indicates a primitive type of stroma where the grouping of the perithecia, or the formation of

a compound fruit body, has not yet taken place. The asci and spores formed in culture were identical with those found in nature. The ostioles in culture were somewhat longer than under natural conditions.

Saccardo (10) gives *Phoma arctii* (Lasch.) Sacc. as the imperfect stage of *Diaporthe arctii* (Lasch.) Nit. He gives the ellipsoid spores as $7 \times 3$–$3.5\ \mu$, and the filiform curved "basidia" as $25 \times 1.5\ \mu$. Traverso (11) later placed this species in the genus Phomopsis, where it belongs, as *Phomopsis arctii* (Lasch.) Trav. He gives the fusoid conidia as $7$–$8 \times 3.5\ \mu$. The Phomopsis obtained in culture is apparently this species. The slight discrepancy in the measurements of the alpha conidia probably lies within the range of variation of these spores.

## SUMMARY

1. The cultural connections of the perithecial and conidial stage of five species of Diaporthe were obtained in either single spore or single ascus cultures.

2. *Diaporthe pruni* E. & E., *D. faginea* (Curr.) Sacc., *D. arctii* (Lasch.) Nit. and an unidentified Diaporthe on *Carya glabra*, all of which show a differentiated light-colored entostromatic area bounded by a blackened marginal zone, produced an imperfect stage of the form genus Phomopsis.

3. *Diaporthe marginalis* Pk., which has a sharply distinct ectostroma, and no differentiated entostroma nor blackened zone in the bark tissue of the host, produced a conidial stage belonging in the form genus Melanconium.

4. This correlation of characters in the perithecial and conidial stages coincides with groups of characters previously suggested by the writer for the separation of the genera Melanconis and Diaporthe.

5. Since it is typical of the genus Melanconis, *Diaporthe marginalis* Pk. becomes **Melanconis marginalis** (Pk.), comb. nov.; *Cytospora pruni* Ell. & Dear. becomes **Phomopsis pruni** (Ell. & Dear.), comb. nov.

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## EXPLANATION OF PLATES

### PLATE XXIII

FIG. 1. Vertical section of stroma of *Diaporthe pruni* E. & E. on *Prunus virginiana* L., showing lateral margin of the effuse entostroma bounded by a blackened zone. The perithecia are clustered beneath pustulate extensions of this entostroma within the bark tissue, and pycnidial locules can be seen within these pustulate areas.

FIG. 2. Vertical section of stroma of **Melanconis marginalis** (Pk.), comb. nov., on *Alnus tenuifolia* Nutt., showing typical stromatic structure of this genus, with the sharply defined cylindrical ectostroma; circinate perithecia, and marginal arrangement of the ostioles about the central disc; and the entire lack of any differentiated entostroma or blackened zones within the host substratum.

FIG. 3. Vertical section of *Diaporthe sp.* on *Carya glabra* (Mill.) Spach., showing loosely clustered perithecia, not definitely oriented beneath the scattered ectostromata, and the dorsal blackened zone of the slightly pustulate, effuse entostroma.

### PLATE XXIV

Fig. 1. Vertical section of stroma of *Diaporthe arctii* (Lasch.) Nit. on Arctium, showing lateral margin of the effuse entostroma bounded by a blackened zone and containing numerous, scattered, separately erumpent perithecia.

FIG. 2. Vertical section of stromata of *Diaporthe faginea* (Curr.) Sacc. on *Fagus grandifolia* Ehrh., showing perithecia clustered within strongly pustulate areas of an effuse entostroma, which is outlined by a very faint blackened zone.

### PLATE XXV

FIG. 1. Vertical section of pycnidial stroma of *Diaporthe pruni* E. & E. from a culture on *Prunus serotina* Ehrh.

Fig. 2. Ascus of *Diaporthe pruni.*

FIG. 3. Ascospores of *Diaporthe pruni.*

FIG. 4. Fusoid-elliptical (alpha) type of conidia produced in cultures of *Diaporthe pruni.*

FIG. 5. Cylindrical (beta) type of conidia produced in cultures of *Diaporthe pruni.*

FIG. 6. Vertical section of conidial fruit body of **Melanconis marginalis** (Pk.), comb. nov., as formed in culture on twigs of *Alnus glutinosa* Gaertn.

FIG. 7. Ascus of *Melanconis marginalis.*

FIG. 8. Ascospores of *Melanconis marginalis.*

FIG. 9. Fusoid-elliptical, dilute blackish conidia formed in cultures of *Melanconis marginalis.*

FIG. 10. Cylindrical hyaline type of conidia produced in cultures of *Melanconis marginalis.*

FIG. 11. Vertical section of pycnidial stroma of *Diaporthe faginea* (Curr.) Sacc. as formed in culture on *Fagus grandifolia* Ehrh.

FIG. 12. Ascus of *Diaporthe faginea.*

FIG. 13. Ascospores of *Diaporthe faginea.*

FIG. 14. Fusoid-elliptical (alpha) type of conidia produced in cultures of *Diaporthe faginea.*

FIG. 15. Curved, filiform (beta) type of conidia produced in cultures of *Diaporthe faginea.*

PLATE XXVI

Fig. 1. Vertical section of pycnidial stroma of *Diaporthe sp.* as formed in culture on twigs of *Carya glabra* (Mill.) Spach.

FIG. 2. Ascus of *Diaporthe sp.* on Carya.

FIG. 3. Ascospores of *Diaporthe sp.* on Carya.

FIG. 4. Fusoid (alpha) type of conidia produced in cultures of *Diaporthe sp.* on Carya.

FIG. 5. Hamate filiform (beta) type of conidia produced in cultures of *Diaporthe sp.* on Carya.

FIG. 6. Vertical section of pycnidial stroma of *Diaporthe arctii* (Lasch.) Nit. as formed in culture on stems of Arctium.

FIG. 7. Ascus of *Diaporthe arctii.*

FIG. 8. Ascospores of *Diaporthe arctii.*

FIG. 9. Fusoid-elliptical (alpha) type of conidia produced in cultures of *Diaporthe arctii.*

FIG. 10. Hamate filiform (beta) type of conidia produced in cultures of *Diaporthe arctii.*

PLATE XXIII

FIG. 1

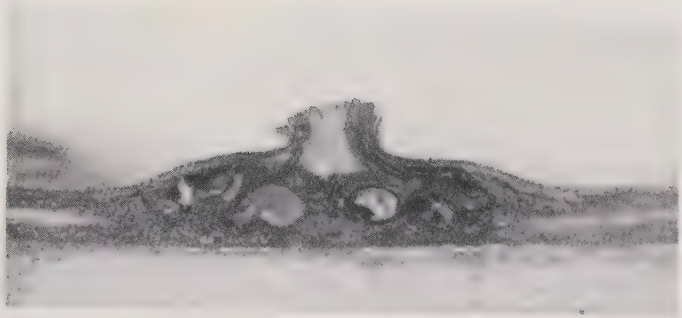


FIG. 2

FIG. 3

PLATE XXIV

FIG. 1

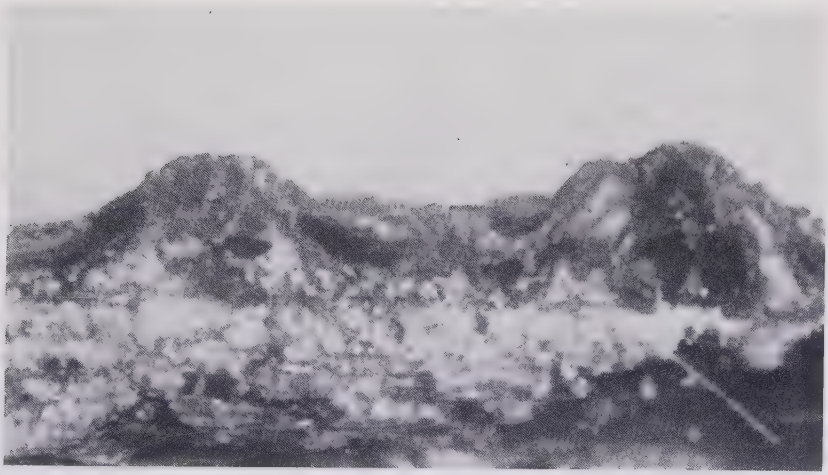
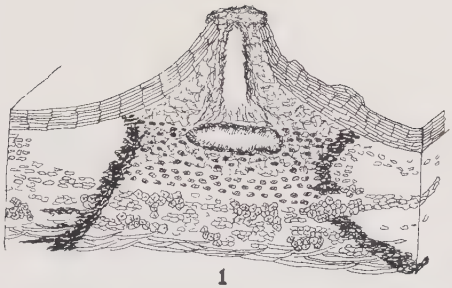


FIG. 2

# PLATE XXV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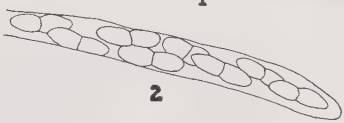
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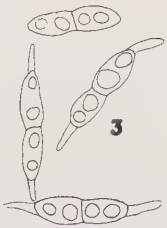
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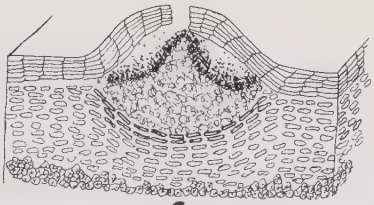
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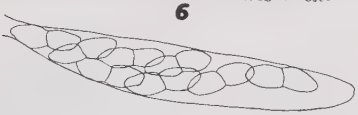
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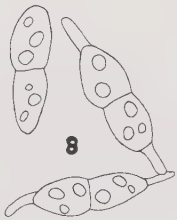
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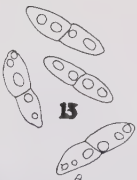
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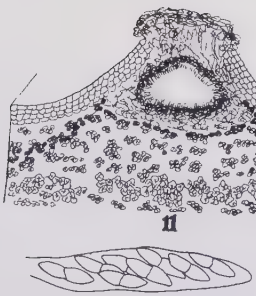
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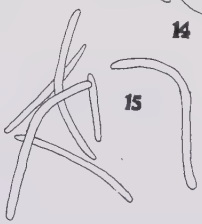
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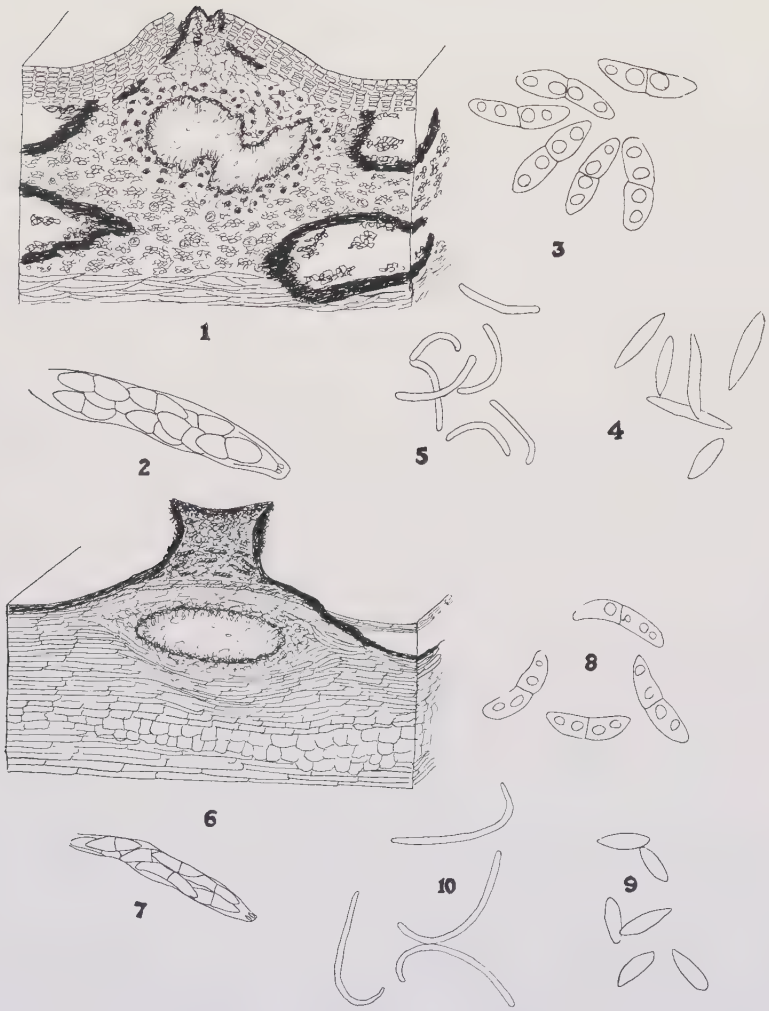
# PLATE XXVI



# MORPHOLOGICAL STUDIES OF THE SEED OF *ALSINE MEDIA*

EDWARD F. WOODCOCK

THE Order Caryophyllales or Centrospermae of Engler and Prantl includes those plants which are characterized by a curved embryo, which is usually surrounded by a nourishing tissue. Malligson (7) has found by serum diagnostic investigations that the families included in this order are closely related. The exact nature of the storage tissue, however, is in question among investigators. Harz (3) considers the principal storage region perisperm, endosperm only appearing in a few cases as a cap over the root end of the embryo. In giving the general characters of some of the important families of the order such as Polygonaceae and Caryophyllaceae, Britton and Brown (2) in their *Flora of the Northern United States, Canada and the British Possessions* have called the storage tissue outside the embryo endosperm.

Bentham and Hooker (1) in their *Genera Plantarum* speak of the storage tissue outside the embryo in the Curvembryeae as "albumen." Johnson (4, 5), working on the Piperaceae, found that in certain species the embryo is separated from a perisperm storage region by a digestive endosperm. Apparently influenced by the observations of Harz (3), Johnson stated that a similar condition existed in the Polygonaceae, Chenopodiaceae, Phytolaccaceae and Caryophyllaceae.

Stevens (6) found that the condition suggested by Johnson for the Polygonaceae did not hold true for the genus Fagopyrum, the storage region being entirely endosperm.

The writer (8, 9) made a study of five other genera of the Polygonaceae and found that in all cases the storage region consisted of endosperm without any evidence of perisperm being present.

The Phytolaccaceae and Portulacaceae have also been investigated by the writer (10, 11) and a storage region of perisperm only was noted, no indication of a digestive endosperm region being present. During the later development of the seed in Phytolaccaceae the embryo was found to be surrounded by a cellular endosperm which disappeared in the mature seed except for a cap of vacuolated cells over the radicle end of the embryo. A similar sheath of vacuolated, somewhat distorted cells surrounds the mature embryo in the Portulaccaceae.

The present paper has to do with the morphology of the seed in *Alsine media* L. Other genera of the Caryophyllaceae will be studied later and the results published.

## DESCRIPTION AND DISCUSSION OF THE MORPHOLOGY OF THE SEED

The stages of seed development were studied from microtome sections stained in Delafield's Haematoxylin. The structure of the young ovule and the early stages of development resemble very closely the condition found by the writer in *Claytonia virginica.*

The ovules are laterally compressed, campylotropous, and somewhat kidney-shaped (Pl. XXVII, Fig. 1). The long narrow curved embryo sac occupies a central position in the ovule. The embryo sac is separated from the inner integument and the micropyle by three or four layers of nucellus tissue. The curved embryo sac partially encircles a hook-like portion of the nucellus. The inner integument consists of two layers of symmetrical, flattened cells, the cells of the inner layer being quite similar to those of the inner integument, but the cells of the outer layer are somewhat larger. In a portion of the outer integument there appear cells in which the radial walls have given away from the outer walls at their point of attachment, thus allowing the outer walls of two or three adjacent cells to form a common dome-shaped wall over the two or three cells.

The early nuclear and cell divisions of the fertilized egg produce a filament of several cells which soon shows marked differentiation in size and function. The micropylar portion be-

comes differentiated into the suspensor, the cell nearest the micropyle being much longer and broader than the other three. This large basal or micropylar cell of the suspensor is said by some investigators to be common in the Centrospermae. The writer found the statement to be true for *Claytonia virginica*, but not for the Polygonaceae or Phytolaccaceae in the genera studied. This large suspensor cell has a conspicuous vacuole in the broad part of it, while the remaining suspensor cells are filled with dense protoplasm. The remaining cells of the suspensor in *Alsine media* are narrower and flattened. The embryo at this stage is spherical and shows no differentiation into radicle, cotyledons and plumule. The embryo sac is lined with a layer of cytoplasm in which are embedded numerous endosperm nuclei. There is no indication of starch formation as yet in any of the cells of nucellus.

As growth continues changes occur in the ovule as shown in Figure 2. The dome-shaped compound cells shown in Figure 1 have now become more numerous and extend about three fifths the distance around the ovule. The embryo sac has become somewhat broader and cell-wall formation has appeared in the micropylar portion of the endosperm. This cellular condition merges into the free nuclear condition. The suspensor has undergone very little change except that the micropylar portion of the large suspensor cell has become somewhat shrivelled and embedded in the cellular endosperm. The embryo has become elongated and flattened on the cotyledon end. There is an indication of stelar differentiation in the form of elongated cells through the central portion.

The appearance of starch grains in the cells of the nucellus in the stage just described is of importance to note. The cells in the hook-like portion are completely filled with starch grains (Fig. 4), while the cells in the chalazal region have a smaller number of grains present (Fig. 3). The relative size of the starch grains and the nucleus is shown in Figures 3 and 4. The individual starch grains are compound, being made up of numerous small grains (Fig. 5). The nucellus tissue between the embryo sac and the integuments show no starch grains present.

During the further growth of the seed no very marked changes take place in the nucellus except that practically all the cells become completely filled with starch grains except the layer of cells between the embryo sac and the integuments. In the stage shown in Plate XXVIII, Figure 7, the cotyledons of the embryo have become well developed, but no indication of a plumule is evident. The suspensor appears only as crushed cell remains. The relative amount of cellular endosperm and free nuclear endosperm has not changed to any extent.

In the mature condition shown in Figure 8, there is evident a well-developed embryo which is curved and extends nearly the entire distance around the periphery of the seed. About two thirds of the embryo consists of radicle and hypocotyl, the remaining portion consisting of semicircular cotyledons, their flat surfaces in contact and at right angles to the flat surface of seed. There is present a well-developed plumule at the base of the cotyledons in the mature embryo. The nucellus between the embryo and seed coat has become completely crushed, and the portion of nucellus nearly encircled by the embryo is made up of cells which are densely filled with starch grains. The tip of the radicle is surrounded by a cap of cellular endosperm which was formed early in the development of the seed. The cells which make up this cap (Pl. XXVII, Fig. 6) have a large nucleus and are densely filled with cytoplasm. Perhaps this layer may have the digestive power suggested by Johnson, but it hardly seems possible that it can play any very important part, considering the relatively small amount in proportion to the amount of perisperm present in the mature seed. A few of the mature seeds were germinated and this cellular endosperm was evident as a sheath about the radicle when it appeared outside the seed coats. A careful study of the seed germination is being made to determine what changes occur in the seed during the process. In Plate XXVII, Figure 6, it is interesting to note that the dermatogen, periblem and plerome are quite distinct in the radicle of the mature embryo. The outer layer of the integument has become transformed into the hard protective part of the seed coat. The cell walls have become much thickened and the cell lumen

filled with dark staining material (Pl. XXVIII, Fig. 9), thus forming a hard brown protective coat about the seed.

Some very interesting features appeared in a study of the form of the mature seed and in the external characters. The flattened seed, in side view, is circular in outline (Fig. 11) with a cleft at one side which represents the region of attachment to the ovary wall. Distinct surface elevations, whose origin was described above, appear in regular rings, eccentric to one another. The edge view of the seed is shown in Figure 10. The seed appears rectangular in outline in this view and the surface elevations are arranged in regular rows.

## SUMMARY AND CONCLUSIONS

The ovule in *Alsine media* is a campylotropous structure, in which the embryo sac occupies a curved peripheral position in the nucellus. The endosperm becomes cellular in the micropylar portion early in the development of the seed, the remaining endosperm never developing beyond the free nuclear condition. The embryo development is quite similar to Bursa. In the mature seed the well-developed curved embryo lies in contact with the seed coat and partially encircles the starchy perisperm. There is evident a cap of endosperm tissue over the radicle end of the embryo, whose cells are filled with dense protoplasmic material.

The striking similarity of seed development in *Alsine media* and *Claytonia virginica* indicates that the Caryophyllaceae and Portulacaceae are very closely related, at least, to judge from the writer's studies in the foregoing genera. It hardly seems possible that the cap of endosperm present in *Alsine media* can have as much digestive power as suggested by Johnson.

Michigan State College
East Lansing, Michigan

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PLATES XXVII–XXVIII

PLATE XXVII

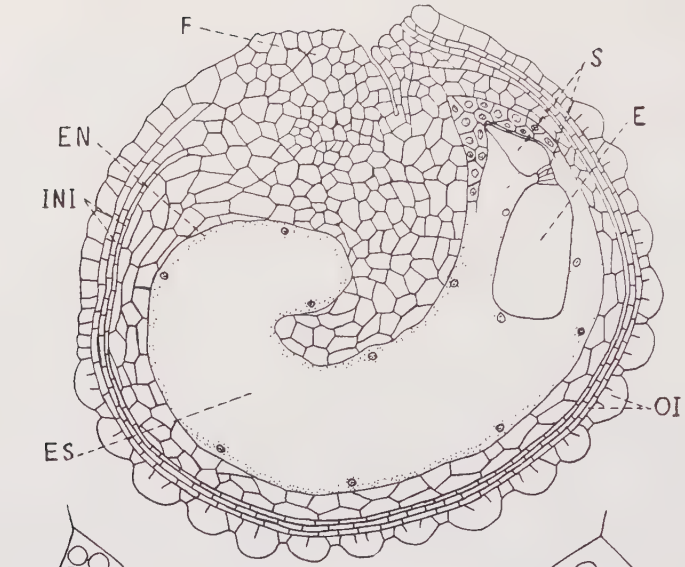


Fig. 2

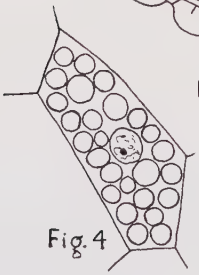

Fig. 4

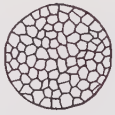

Fig. 5

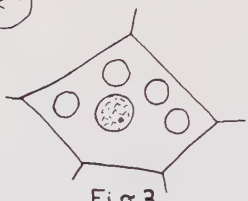

Fig. 3

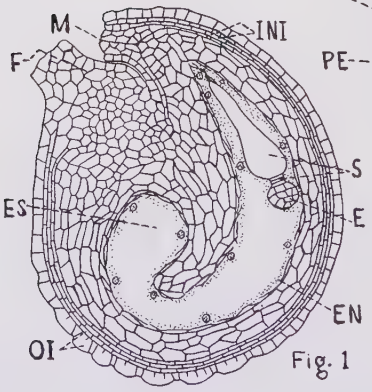


Fig. 1

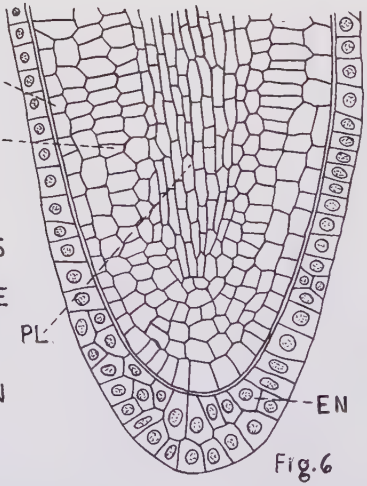


Fig. 6

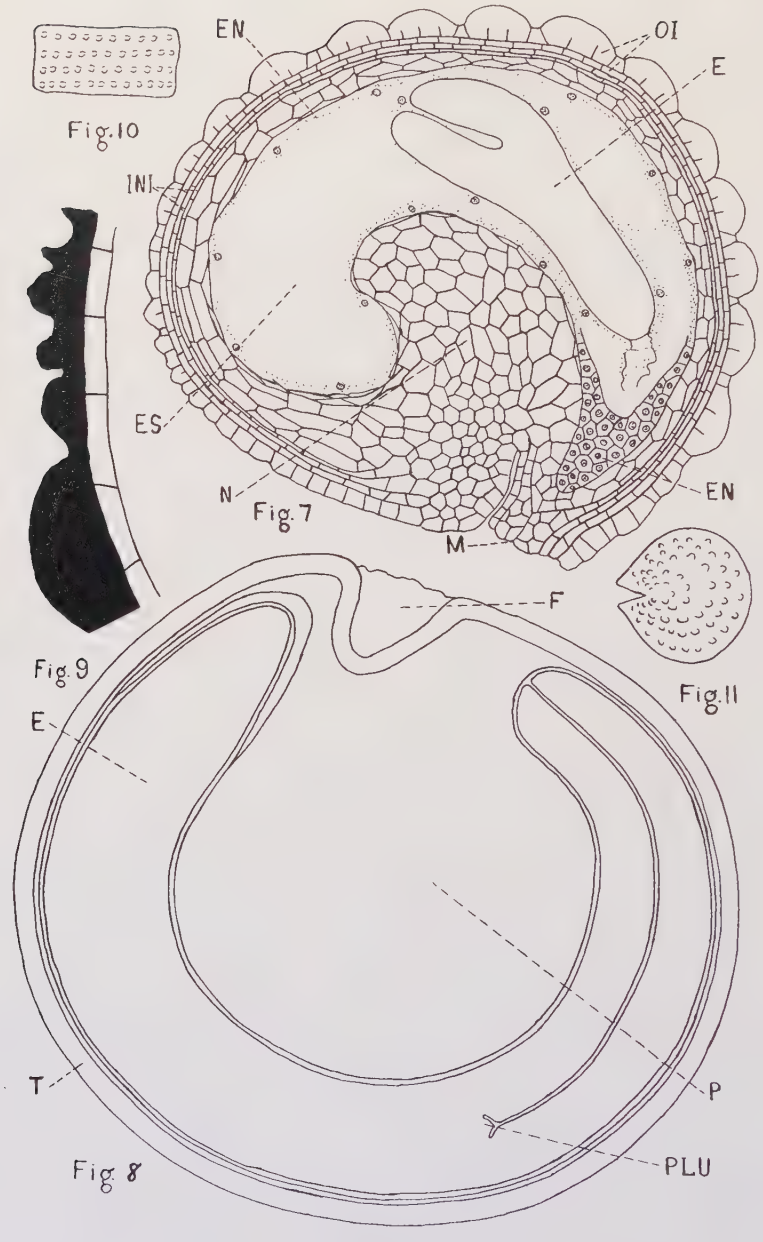
EN
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Fig. 10
INI
ES
N
Fig. 7
M
EN
F
Fig. 9
Fig. 11
E
T
P
PLU
Fig. 8

## DESCRIPTION OF PLATES

All figures drawn from median longitudinal sections cut parallel to flat surface of the seed. The following abbreviations are used: E, embryo; ES, embryo sac; S, suspensor; P, perisperm; T, testa; M, micropyle; F, funiculus; N, nucellus; EN, endosperm; OI, outer integument; INI, inner integument; DE, dermatogen; PE, periblem; PL, plerome; PLU, plumule.

### PLATE XXVII

FIG. 1. Young ovule, showing campylotropous form, embryo sac, embryo in young spherical condition, and endosperm in free nuclear condition (× 75).

FIG. 2. An older stage, showing an increase in the size of the embryo sac and the number of endosperm nuclei. The endosperm has become cellular in the micropylar region (× 75).

FIG. 3. Cell of nucellus from chalazal region of stage shown in Figure 2. Large compound starch grains appearing about the nucleus (× 207).

FIG. 4. Cell of nucellus from the central hook-like portion shown in Figure 2. Cell cavity packed nearly full with compound starch grains (× 430).

FIG. 5. Single compound starch grain (× 1760).

FIG. 6. Root end of hypocotyl of mature embryo showing the cap of cellular endosperm, and the dermatogen, periblem and plerome (× 207).

### PLATE XXVIII

FIG. 7. Stage of seed development showing well-developed cotyledons in the embryo. A slight increase in the amount of cellular endosperm is evident. At this stage practically all of the cells of the nucellus are filled with compound starch grains (× 75).

FIG. 8. Mature seed showing curved embryo about the centrally placed perisperm. The endosperm appears as a cap over the end of the hypocotyl (× 75).

FIG. 9. Transverse section of outer integument of mature seed (× 207).

FIG. 10. Diagram of edge view of mature seed showing form and arrangement of surface elevations.

FIG. 11. Diagram of flat surface of mature seed showing form and arrangement of surface elevations.

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